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NATIONAL GEOGRAPHIC

THE **MONSTER** STORM



The greatest storm chaser, Tim Samaras devoted his life to unlocking the mysteries of extreme weather.

Then came the tornado of May 31.

Samaras deploys probes in 2003.



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TOYOTA | Let's Go Places

VOL. 224 • NO. 5

NATIONAL GEOGRAPHIC

I asked—the stupidity of my question apparent immediately—"Are you OK?"
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A clownfish hides in an anemone in Papua New Guinea's Kimbe Bay.

DAVID DOUBILET

November 2013

28 Last Days of a Storm Chaser
For years Tim Samaras pursued tornadoes for the sake of science, always taking great pains to stay safe. Then came the storm of May 2013.
By Robert Draper

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Seventeen years ago David Doubilet fell in love with the reefs of Kimbe Bay. At long last, he has returned to the Pacific paradise.
By Cathy Newman Photographs by David Doubilet

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On a venture to rival Lewis and Clark's, we're exploring our vast watery frontier.
By Robert D. Ballard

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They call it "the crisis": Islamist terrorists are trying to gain control of the north.
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It has 63,000 miles of fjords, bays, island shores.
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In her airtight space suit she looks for cures.
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When digging is taboo, fate may unearth the past.
By A. R. Williams

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY

November 2013

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A Tax on Pop
A growing number of nations believe that's the way to cut soda consumption.



Sponging Off a Canal
A Brooklyn waterway aims to clean up—and draw tourists—with "sponge parks."

Black Death Hangs On
The plague is surprisingly persistent.

Rebuilding Beaches
To keep tourists happy, towds do it again…and again…and again.



Sad Rats
Their depression can be blamed on too much daylight.

How a Turtle Grows a Shell
New answers to questions about how it develops.



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Flashback

On the Cover Tim Samaras loved chasing storms—like this 2003 tornado near the town of Manchester, South Dakota. Throughout his career, his goal was to place probes to collect data about the nature of storms. He died in the tornado that hit El Reno, Oklahoma, on May 31, 2013.
Photo by Carsten Peter

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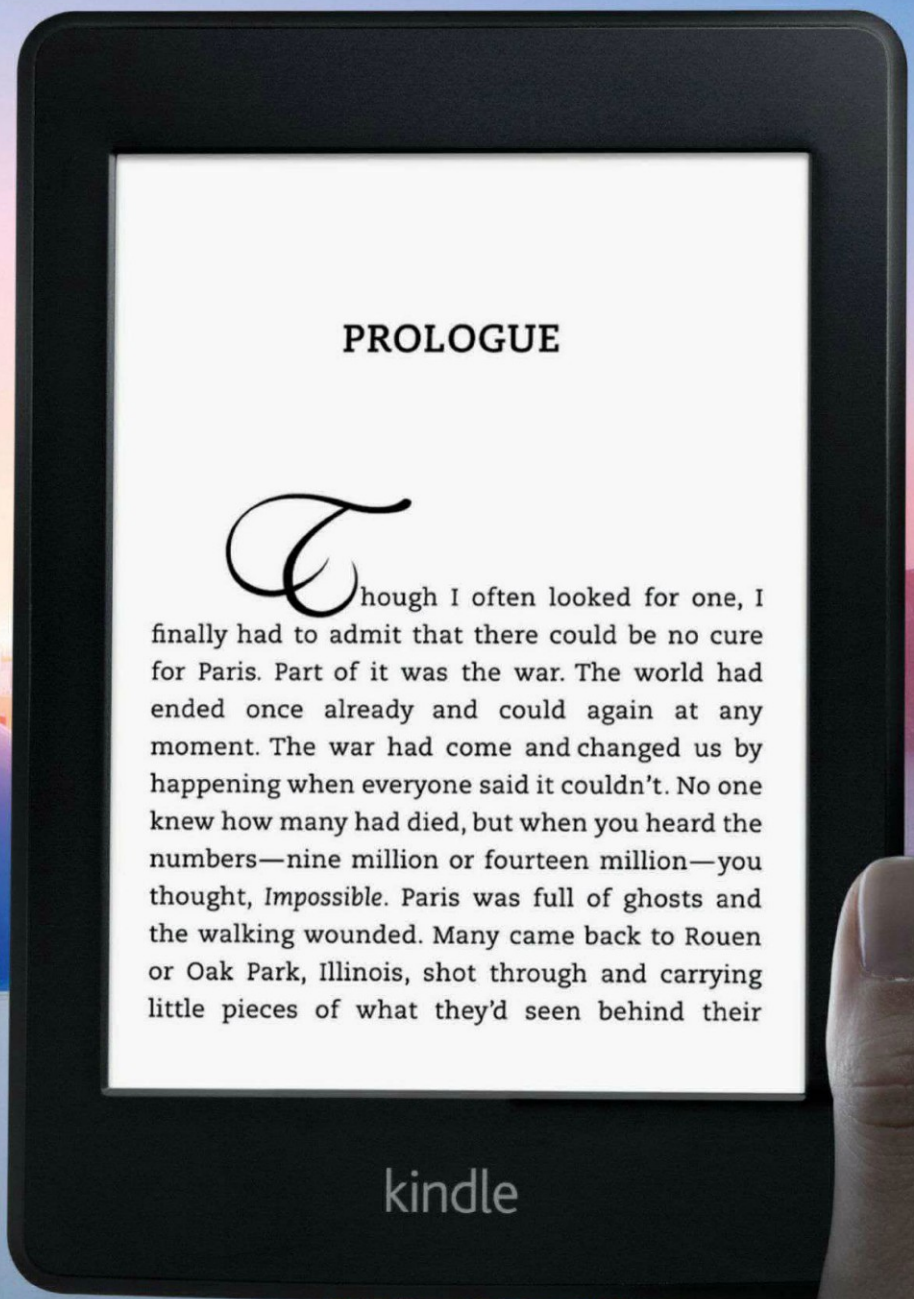


Risk Taker
Video
Hear why Vicki Jensen handles deadly viruses.

PHOTOS: CARSTEN PETER, NATIONAL GEOGRAPHIC CREATIVE (TOP); LEANDRO BLANCO (MIDDLE)

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Bearing Witness

In the photograph the woman's face is etched with anxiety. She is crossing a street with her family on their way to church. The black metal carapace of a water-cannon truck looms in the background. You can sense she is walking quickly. The streets of Kano, in northern Nigeria, are dangerous and no place to linger. It's all there in the picture—fear, apprehension, defiance, and, in the black truck, a reminder of the daily brutality people face.

Why cover a place so full of sadness?

Why cover a place, as we do this month, like northern Nigeria—a place so beset by insurgency and corruption, so full of sadness and violence?

"To tell stories that need to be told," answers Ed Kashi, the story's photographer. To bear witness. To hope the story adds to the conversation. Perhaps to make a difference.

"We tend to forget that in much of the world people live not just in poverty but close to death and violence," author James Verini says. "They live in places where governments don't care about them. The question I like to ask is, What do you do, how do you survive, when death is so near and you have no options?"

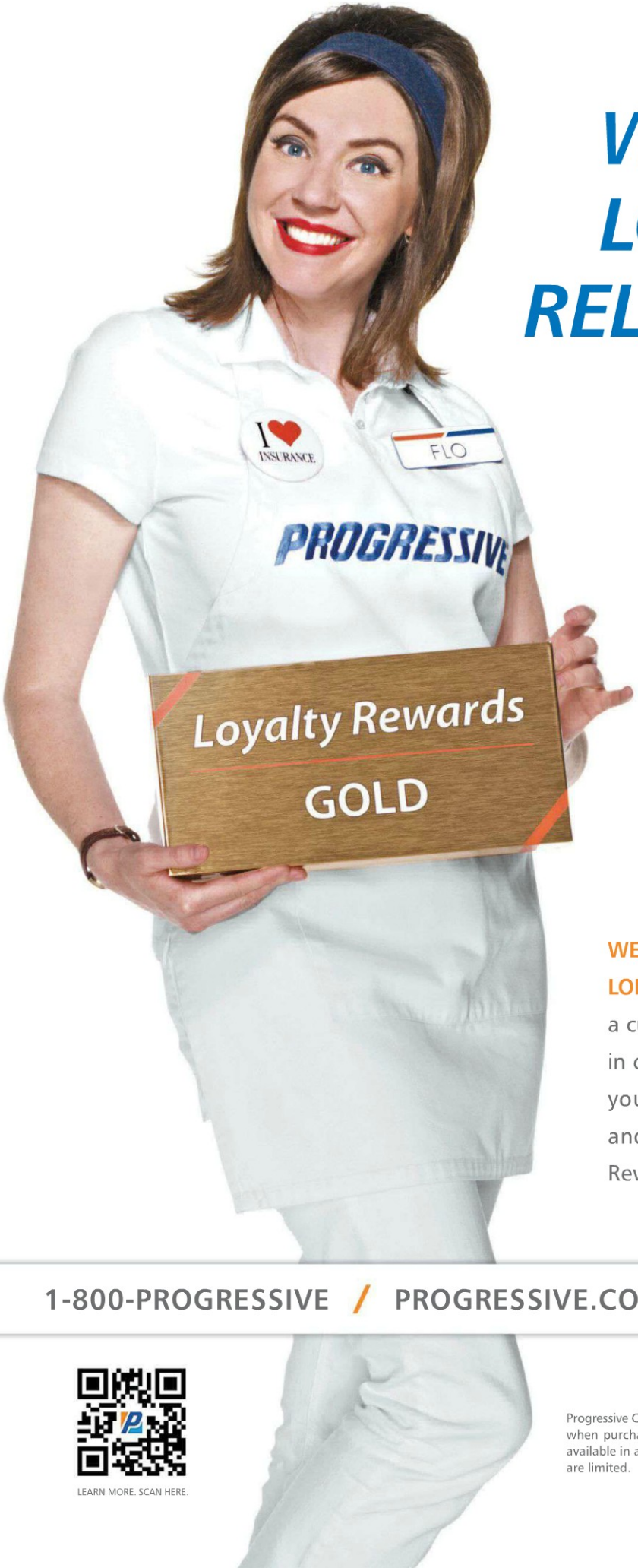
Who will speak for this woman crossing the street? Not the government. Not the terrorists who bomb churches, schools, and mosques. Violence, we know all too well, has no borders. It matters that we pay attention to and report these stories. "When I see someone struggling, it's in my DNA to help," Ed Kashi says.

If only by bearing witness to a frightened woman crossing the street.



A family braves the streets of Kano in northern Nigeria. James Verini's "The War for Nigeria" begins on page 86 of this issue.

PHOTO: ED KASHI



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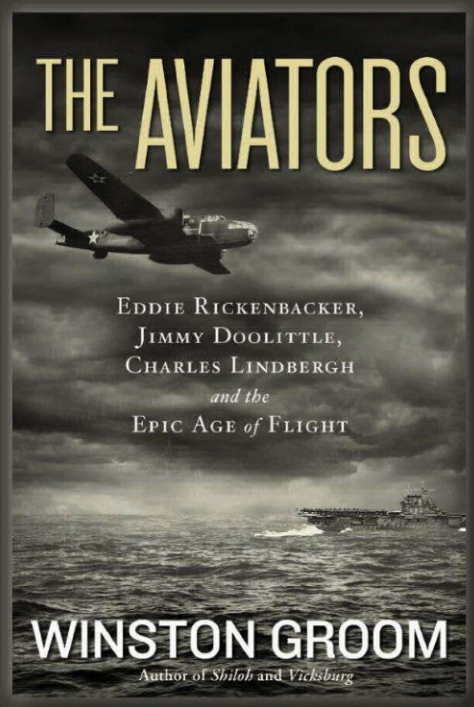
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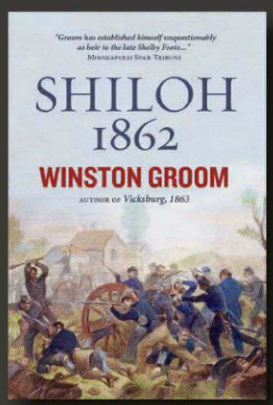
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—Publishers Weekly

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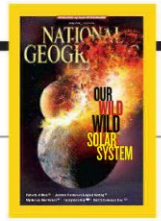
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Songbird Slaughter

Photographer David Guttenfelder was certainly right when he said that "this isn't how birds are supposed to be" after witnessing illegally caged birds. So thank you. However, in the same issue there is a photo of parakeets or budgerigars looking at themselves in a mirror. Do you not think that this also is not how birds are supposed to be? Even if they are bred in captivity, they must surely have a strong instinct to fly. Their wings are not ornaments. A room in a house is only marginally better than a cage. What bird would choose to live inside and never feel the wind?

JUDE KIRK
Denman Island, British Columbia

I guess my concern about the neighborhood cats' hunting prowess is of little matter. Don't the Europeans miss the splash of color and song of the little ones as they pass through?

ROGER WILSON
Santa Rosa, California

It had occurred to me that for all the hundreds of songbirds that visit my land I've never found a dead one. That raised the question, Where do birds go to die? I had decided the birds are so beautiful in song and plume that God must take them directly into his care. Then I read this article. Sadly I must now admit my theory has little merit. I know now where they go.

RONALD R. CARROLL
Neosho, Missouri

Emily Dickinson's poem with the line "'Hope' is the thing with feathers / That perches in the soul" came to mind in cruel contrast to Guttenfelder's photos, which captured compelling images of helpless birds caught on glue sticks, trapped under nets, and dangling off guns like miniature trophies.

BETSY COMEAU
Long Lake, New York

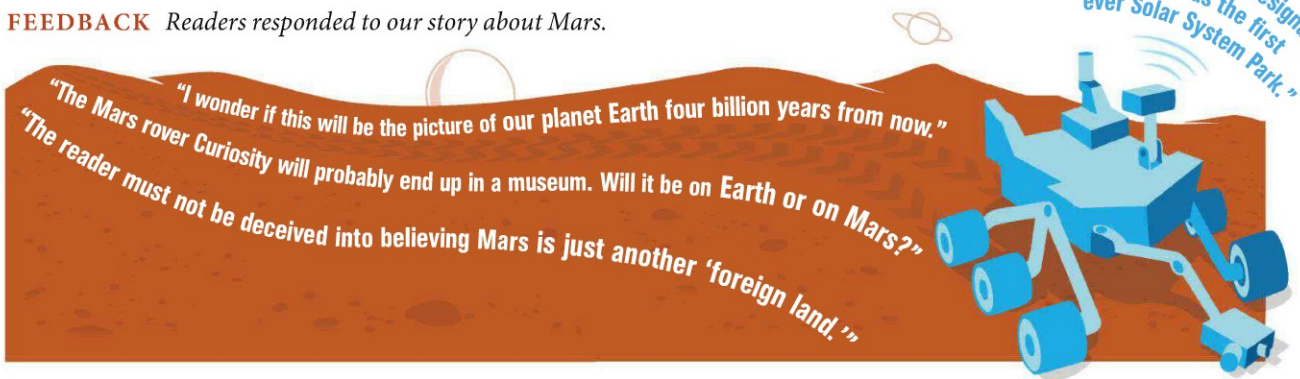
These birds are beneficial creatures, and their being subjected to this onslaught on their annual migration is just barbaric and obscene. Moreover, the increasing number killed is unsustainable, and it will drive some of the most vulnerable species to extinction. Think of the carrier pigeon. When I was a boy in Yorkshire, you not only heard the cuckoos in spring, you saw them. In the past two years I have traveled around England and Scotland and have not heard a single cuckoo. Now I know why, and it hurts.

RONALD BARNES
Norfolk, England

I wish there were a feel-better ending, but it wasn't to be found.

SUZE PEACE
DeLand, Florida

FEEDBACK *Readers responded to our story about Mars.*



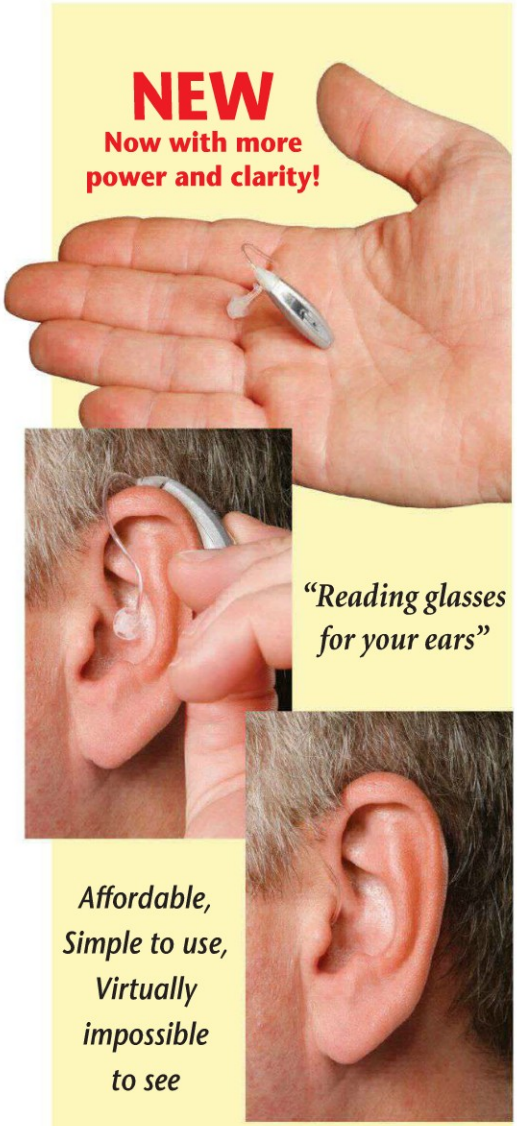
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LETTERS

Mars

Thank you for the continuing reports on the effort on Mars, particularly for articles authored by those directly involved with the work. John Grotzinger's enthusiasm for the various Mars projects is evident in every sentence. Those of us who as teens knew him at summer camp are impressed—but not surprised.

PAUL J. LUBY
Stafford Springs, Connecticut

It occurred to me that the contents of the crater, and probably Mount Sharp especially, would be remnants of the meteor that formed the crater and not part of the Mars planet itself.

LARRY D. LAWRENCE
Stevens Point, Wisconsin

According to Curiosity's chief scientist, John Grotzinger: We don't see meteor remnants forming mountains on that large a scale on the moon or Mercury, so scientists don't consider it to be a possibility for Mars.

Spectacular as the images of the Martian landscape may be, for me they only serve to reinforce one undeniable fact: that we live on a planet of such beauty that it may well be unique in the universe. Perhaps we should take better care of it.

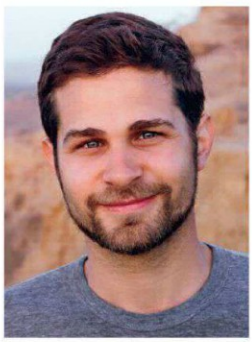
PETER MEYER
Hamilton, Ontario

Transylvania Hay

The article decries the threats to tradition, such as the EU's incentives for hay made after July 1 rather than the traditional date of June 24. Some calendars have only been in use for several hundred years and vary considerably in their date-calculation systems—Orthodox and Julian calendars can vary by weeks. This is just one example of holding to a tradition that is not long in establishment and completely arbitrary as well.

MARLA K. KING
Everett, Washington





Andrés Ruzo
National Geographic
Young Explorer Grantee

EXPERTISE
Geothermal scientist

LOCATION
Peru

Boiling Point

As a geothermal scientist, I knew that boiling rivers exist—but they're always near volcanoes. You need a lot of heat to make that much water boil. We were working in the volcanic gap, a 950-mile stretch that covers most of Peru, where there hasn't been active volcanism for the past two million years.

Yet we'd found the Shanaya, a name derived from "heated thing." My measurements averaged 190°-195°F. The locals think it's so hot because of the Yacumama, or "water mother"—a spirit who gives birth to waters—represented by a serpent-head–shaped rock at the origin of the heated water.

I had to cut my way through the brush at the side of the river to take temperature readings. All the while, right next to me was this very hot, fast-flowing body of water the width of a two-lane street. The shaman at the nearest village had told me, "Use your feet like eyes." You can't see heat, but you can feel it when you step near it. I wore sandals.

I was at a part of the river measuring 210°F, standing on a rock the size of a sheet of paper, when the rain turned on. It was like a curtain rising: The temperature differential between the rain and the river caused a white-out. I couldn't see, but I whistled to let my partner know I was OK.

At 130°F flesh cooks, and the water around me was nearing twice that. My eyes would have cooked in less than a minute, and I couldn't have seen how to get out. I'd seen rats and an opossum fall in, their eyes turning milky white. I kept whistling.

After 15 minutes the rain stopped and the steam cleared. A hard rain in most situations would have been inconsequential. Here, for a matter of minutes, it thinned the line between researching and being boiled alive.



ART: ISTVAN BANYAI. PHOTO: SOFÍA RUZO

For people with a higher risk of stroke due to Atrial Fibrillation (AFib) not caused by a heart valve problem



I was taking warfarin. But I wondered, could I shoot for something better?

NOW I TAKE ELIQUIS® (apixaban) FOR 3 GOOD REASONS:

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ELIQUIS and other blood thinners increase the risk of bleeding which can be serious, and rarely may lead to death.

Ask your doctor if ELIQUIS is right for you.

ELIQUIS is a prescription medicine used to reduce the risk of stroke and blood clots in people who have atrial fibrillation, a type of irregular heartbeat, not caused by a heart valve problem.

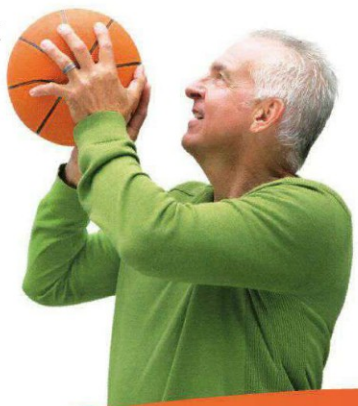
IMPORTANT SAFETY INFORMATION:

- **Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke.** ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.
- **ELIQUIS can cause bleeding which can be serious,** and rarely may lead to death.
- **You may have a higher risk of bleeding if you take ELIQUIS and** take other medicines that increase your risk of bleeding, such as aspirin, NSAIDs, warfarin (COUMADIN®), heparin, SSRIs or SNRIs, and other blood thinners. **Tell your doctor about all medicines, vitamins and supplements you take.** While taking ELIQUIS, you may bruise more easily and it may take longer than usual for any bleeding to stop.
- Get medical help right away if you have any of these signs or symptoms of bleeding:
 - unexpected bleeding, or bleeding that lasts a long time, such as unusual bleeding from the gums; nosebleeds that happen often, or menstrual or vaginal bleeding that is heavier than normal
 - bleeding that is severe or you cannot control
 - red, pink, or brown urine; red or black stools (looks like tar)
 - coughing up or vomiting blood or vomit that looks like coffee grounds
 - unexpected pain, swelling, or joint pain; headaches, feeling dizzy or weak
- **ELIQUIS is not for patients with artificial heart valves.**
- **Before you take ELIQUIS,** tell your doctor if you have: kidney or liver problems, any other medical condition, or ever had bleeding problems. Tell your doctor if you are pregnant or breastfeeding, or plan to become pregnant or breastfeed.
- **Do not take ELIQUIS if you** currently have certain types of abnormal bleeding or have had a serious allergic reaction to ELIQUIS. A reaction to ELIQUIS can cause hives, rash, itching, and possibly trouble breathing. Get medical help right away if you have sudden chest pain or chest tightness, have sudden swelling of your face or tongue, have trouble breathing, wheezing, or feeling dizzy or faint.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

Please see additional Important Product Information on the adjacent page.

Individual results may vary.



Visit ELIQUIS.COM
or call 1-855-ELIQUIS

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Eliquis®
(apixaban) tablets 5mg

IMPORTANT FACTS

Eliquis® (apixaban) tablets / Rx ONLY

The information below does not take the place of talking with your healthcare professional. Only your healthcare professional knows the specifics of your condition and how ELIQUIS® may fit into your overall therapy. Talk to your healthcare professional if you have any questions about ELIQUIS (pronounced ELL eh kwiss).

What is the most important information I should know about ELIQUIS (apixaban)?

Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke. ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.

ELIQUIS can cause bleeding which can be serious, and rarely may lead to death. This is because ELIQUIS is a blood thinner medicine that reduces blood clotting.

You may have a higher risk of bleeding if you take ELIQUIS and take other medicines that increase your risk of bleeding, such as aspirin, nonsteroidal anti-inflammatory drugs (called NSAIDs), warfarin (COUMADIN®), heparin, selective serotonin reuptake inhibitors (SSRIs) or serotonin norepinephrine reuptake inhibitors (SNRIs), and other medicines to help prevent or treat blood clots.

Tell your doctor if you take any of these medicines. Ask your doctor or pharmacist if you are not sure if your medicine is one listed above.

While taking ELIQUIS:

- you may bruise more easily
- it may take longer than usual for any bleeding to stop

Call your doctor or get medical help right away if you have any of these signs or symptoms of bleeding when taking ELIQUIS:

- unexpected bleeding, or bleeding that lasts a long time, such as:
 - unusual bleeding from the gums
 - nosebleeds that happen often
 - menstrual bleeding or vaginal bleeding that is heavier than normal
- bleeding that is severe or you cannot control
- red, pink, or brown urine
- red or black stools (looks like tar)
- cough up blood or blood clots
- vomit blood or your vomit looks like coffee grounds
- unexpected pain, swelling, or joint pain
- headaches, feeling dizzy or weak

ELIQUIS (apixaban) is not for patients with artificial heart valves.

What is ELIQUIS?

ELIQUIS is a prescription medicine used to reduce the risk of stroke and blood clots in people who have atrial fibrillation.

It is not known if ELIQUIS is safe and effective in children.

Who should not take ELIQUIS?

Do not take ELIQUIS if you:

- currently have certain types of abnormal bleeding
- have had a serious allergic reaction to ELIQUIS. Ask your doctor if you are not sure

What should I tell my doctor before taking ELIQUIS?

Before you take ELIQUIS, tell your doctor if you:

- have kidney or liver problems
- have any other medical condition
- have ever had bleeding problems
- are pregnant or plan to become pregnant. It is not known if ELIQUIS will harm your unborn baby
- are breastfeeding or plan to breastfeed. It is not known if ELIQUIS passes into your breast milk. You and your doctor should decide if you will take ELIQUIS or breastfeed. You should not do both

Tell all of your doctors and dentists that you are taking ELIQUIS. They should talk to the doctor who prescribed ELIQUIS for you, before you have **any** surgery, medical or dental procedure.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements. Some of your other medicines may affect the way ELIQUIS works. Certain medicines may increase your risk of bleeding or stroke when taken with ELIQUIS.

How should I take ELIQUIS (apixaban)?

Take ELIQUIS exactly as prescribed by your doctor. Take ELIQUIS twice every day with or without food, and do not change your dose or stop taking it unless your doctor tells you to. If you miss a dose of ELIQUIS, take it as soon as you remember, and do not take more than one dose at the same time. **Do not run out of ELIQUIS. Refill your prescription before you run out. Stopping ELIQUIS may increase your risk of having a stroke.**

What are the possible side effects of ELIQUIS?

- See **"What is the most important information I should know about ELIQUIS?"**
- ELIQUIS can cause a skin rash or severe allergic reaction. Call your doctor or get medical help right away if you have any of the following symptoms:
 - chest pain or tightness
 - swelling of your face or tongue
 - trouble breathing or wheezing
 - feeling dizzy or faint

Tell your doctor if you have any side effect that bothers you or that does not go away.

These are not all of the possible side effects of ELIQUIS. For more information, ask your doctor or pharmacist.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

This is a brief summary of the most important information about ELIQUIS. For more information, talk with your doctor or pharmacist, call 1-855-ELIQUIS (1-855-354-7847), or go to www.ELIQUIS.com.

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Alexander Graham Bell with his grandson Melville. Beinn Bhreagh, Nova Scotia. Copyright © 2013 National Geographic Society

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VISIONS



Puerto Rico
Breezes rustle the ruffles of little dresses hung to dry in Utuado, a mountain town in the island's rural heartland.

PHOTO: AMY TOENSING



THESE IMAGES WILL APPEAR IN *WOMEN OF VISION*, A BOOK AND TRAVELING EXHIBIT FEATURING THE WORK OF *NATIONAL GEOGRAPHIC*'S FEMALE PHOTOGRAPHERS.





Venezuela
Candles help summon the spirit of Maria Lionza, whose namesake cult claims thousands of followers in Latin America. This cleansing ritual, held during believers' annual pilgrimage to Venezuela's Cerro de Sorte, is known as a *velación*.

PHOTO: KITRA CAHANA



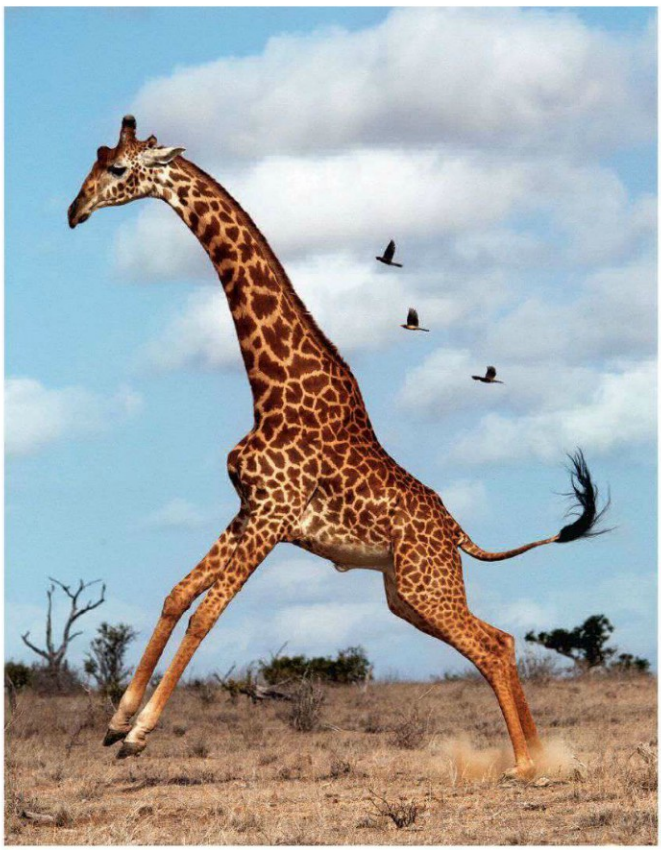
Egypt
In the Sinai Peninsula city of Saint Catherine, members of a Bedouin bride's family—and the groom—celebrate with an impromptu dance after the wedding.

PHOTO: AMY TOENSING



This page features two photographs: one chosen by our editors and one chosen by our readers via online voting. For more information, go to *yourshot.nationalgeographic.com.*





EDITORS' CHOICE

Mo Xizhi Shanghai, China

Mo once discovered by mistake that lightly shaking a camera during a long exposure can create a blurred photo that resembles a painting. On the banks of China's Ou River, he used the method to capture a group of traditional fishing boats and the mist that was rising from the water.

READERS' CHOICE

Manuelo Bececco Perugia, Italy

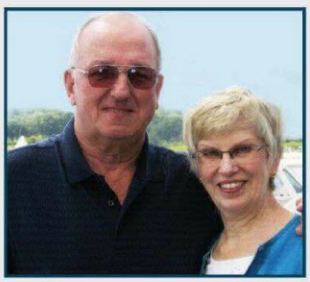
Toward the end of a safari in Kenya, Bececco, who had already spent hours photographing lions, noticed a family of giraffes approaching his group's vehicle. As one of the giraffes began to run, three birds in the distance created, Bececco says, "a harmonious composition."

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NG 2012 Explorer of the Year Gerlinde Kaltenbrunner, the first woman to summit all 8000m peaks without supplemental oxygen.

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The city lights of Los Angeles bounce off high fog and low clouds here. I like to shoot during foggy nights or a full moon.

Sleeping Cars

In Los Angeles County, California, there are more than seven million registered vehicles. Everybody knows about the traffic here. But where do all those cars go to rest? I am a night owl; I don't need much sleep. So in a departure from my usual, more challenging documentary work, sometimes I go out at night and photograph sleeping cars.

My cars have to have a presence. They must command their space and can't be crowded in with others. After a while I recognize their sleeping patterns. Their covers are like nightgowns, though some sleep in the nude. I find covered cars more in L.A. than in other places. In middle-class neighborhoods families own more than one car but only have one-car garages. Many cars are left on the street and often get covered during holidays, when their owners are out of town. Around the Fourth of July is a good time to find them—people cover their beloved cars to protect them from damaging fireworks.

A few times the police have stopped to ask what I'm doing in the middle of the night (I wear an orange vest and set out traffic cones as I work). After I've shown them photographs on my iPad from previous nights, they've even told me about other cars to check out in the neighborhood.

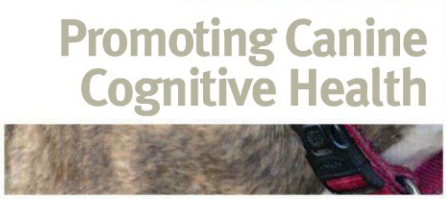
THE PHOTOGRAPHER

Gerd Ludwig is a Los Angeles-based photographer for the Institute agency. Find more of his work at gerdludwig.com.

Chasing Vitality



Promoting Canine Cognitive Health





Doubay, a 12-year-old "pit bull" terrier, shows signs of serious cognitive dysfunction. She wanders aimlessly through the house, has trouble navigating stairs, can't follow simple commands, and is unable to find a treat hidden under a plastic cone. In a subjective assessment of Doubay's condition and faculties, her owner, an experienced animal trainer, gave her a score of one out of ten.

"More than ten years ago, we surveyed owners of senior-age dogs, and it was clear that they just accepted a number of markers that indicate old age in their pets," says Dr. Mark Roos, Director of Global Nutrition and Technical Communications at Nestlé Purina Pet Care. "These include poor mobility, sleep cycle disruption, and soiling in the home."

Deducing that the decline in physical activity could be partially caused by declining cognitive function, senior research scientist Dr. Yuanlong Pan and his team at Nestlé Purina Research started to investigate opportunities for using nutritional approaches to restore cognitive function in older dogs. One of the projects was to address the common phenomenon that indicated that as mammals age, their brains use glucose less effectively as a source of energy, leaving their brains deficient in energy, which leads to cognitive decline.

"We wanted to see if there was another source of energy or an alternate pathway to neuron cells," Dr. Pan says. "After years of research, we found that medium chain triglycerides [MCTs] are processed by the liver into an alternate energy source, ketones, that go to the brain and restore brain function in old dogs." This breakthrough research was published in the British Journal of Nutrition. Building on this research, Dr. Roos' group and a project team developed Purina ONE Vibrant Maturity® 7+ Senior Dog Food containing MCTs in the form of enhanced botanical oils. Now anecdotal evidence is consistent with the published study, indicating that a formula with MCTs is remarkably effective in restoring brain function in older dogs.

After eating a diet rich in MCTs for one month, Doubay is ably walking up the stairs. She has regained her ability to recognize the command for "sit," and quickly locates a treat hidden under a cone. Her owner now gives her an assessment of seven and a half out of ten.

"Dogs typically start to show signs of cognitive decline at about seven years of age," says Dr. Roos, "and pet owners don't have to accept that condition." By helping keep them mentally and physically balanced with Purina ONE Vibrant Maturity® as they age, they will continue to provide balance in your life.

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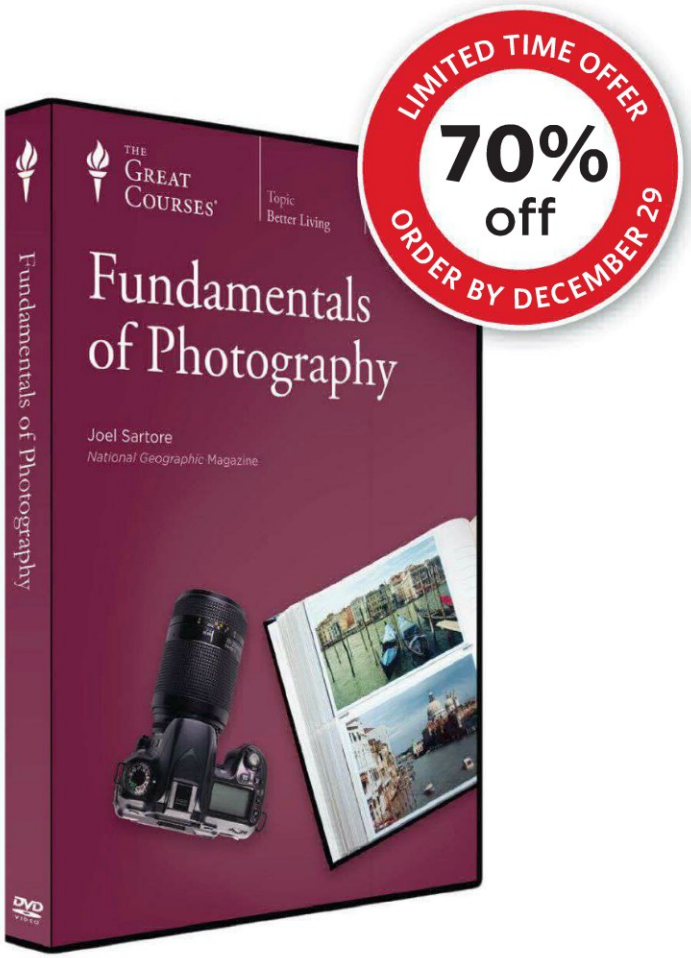


The proud owner of this sleeping Porsche came out when he saw me shooting. Occasionally owners will ask me if I want them to move or uncover the vehicle for the photograph, but I generally don't like to disturb the cars in their sleep.



The cars in this project are photographed as I find them, only I sometimes choose to pop a strobe or two. This often attracts curiosity or even wakes people up in the middle of the night, but once I explain myself, people are usually cool about it.

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I shot this one night with rising fog, somewhere in West Hollywood. Most Los Angeles neighborhoods blend into each other. I don't pay attention to exact locations. Mainly I just cruise in search of cars that speak to me.



Wind rattled the palms and rippled the car covers this night in the Hollywood Hills.



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KILLING KENNEDY

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NEXT

SKYCAST

Overhead this month in parts of the world

November 16-17

Leonid meteor shower at peak, though the full moon might make viewing difficult.

GLOBAL VIEW

Soft drinks are taxed in some countries (represented by containers showing their currencies, clockwise from top), including:

Nauru, since 2007

U.S. (Baltimore, Maryland), since 2010

France, since 2012

Algeria, since 2011

Fiji, since 2006



Soda Stand

There's no way to sugarcoat it: Obesity is a global problem. Once found largely in industrialized places, the condition is now on the rise in developing nations too—and sweet beverages are partly to blame.

Taxing could help curb the trend. In recent years at least ten countries have introduced surcharges on sugary drinks in an effort to reduce consumption. The U.K. is considering a tax; on the Pacific island of Nauru, where most people are overweight, both sodas and flavored milks are taxed.

Oliver Mytton, who studies public health at Oxford, says markets are feeling the impact. In France, for instance, fewer sweet drinks have been sold since a 2012 tax was implemented. What isn't clear yet is how much the levies are affecting waistlines. Still, says Mytton, they're "a step in the right direction." *—Catherine Zuckerman*

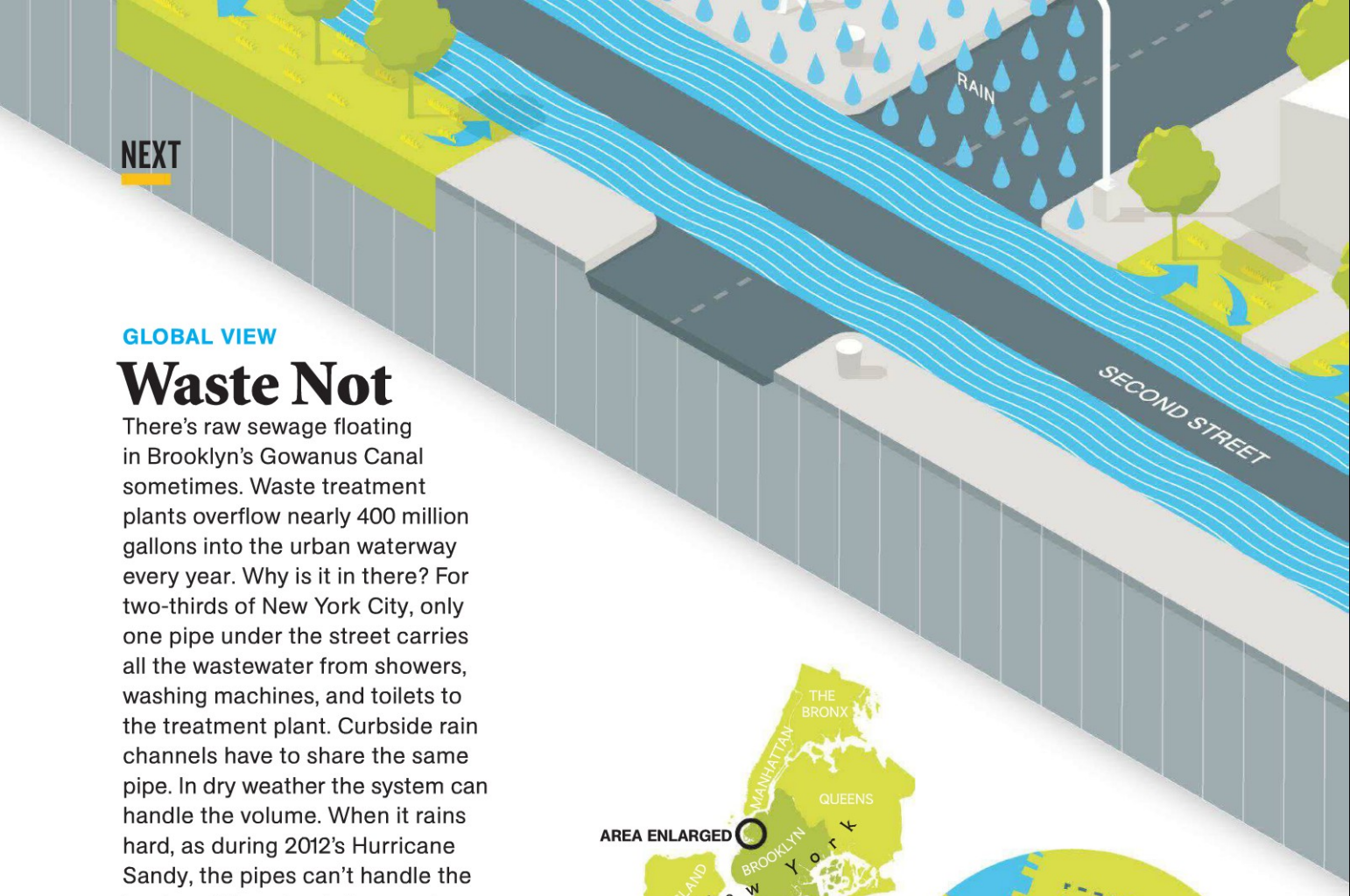
ART: HANNAH TAK, NGM STAFF. PHOTO: MARK THIESSEN, NGM STAFF

GLOBAL VIEW

Waste Not

There's raw sewage floating in Brooklyn's Gowanus Canal sometimes. Waste treatment plants overflow nearly 400 million gallons into the urban waterway every year. Why is it in there? For two-thirds of New York City, only one pipe under the street carries all the wastewater from showers, washing machines, and toilets to the treatment plant. Curbside rain channels have to share the same pipe. In dry weather the system can handle the volume. When it rains hard, as during 2012's Hurricane Sandy, the pipes can't handle the load, and the mix of storm water and sewage ends up in adjacent waterways. It's a common problem in American cities with water systems reaching the hundred-year mark—development aboveground is outpacing the cities' capacity to channel liquid waste.

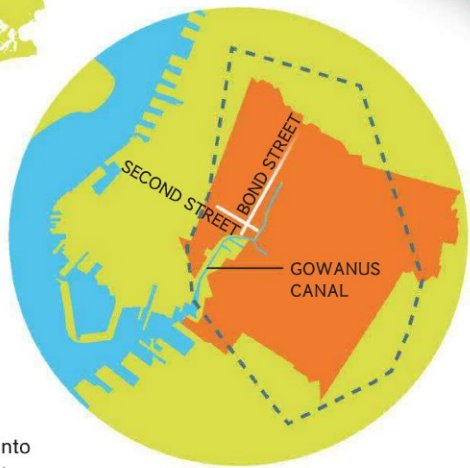
Gowanus is testing a countermeasure. Next year construction begins on a "sponge park," a series of 10-by-5-foot plant-filled pits dug into the canal's edge. They're meant to soak up rainwater before it can make its way into sewage pipes. The area will double as a park. "Space is at such a premium in New York, we don't have room for one-trick ponies," says NYC Parks & Recreation's Nette Compton, who helped carve out city space for the project. There are side benefits too. Greenery in similar sites around NYC is healthier than plants elsewhere because it gets watered so regularly. Plus the additional evaporation cools the area, helping offset heat from nearby industry. Says Compton, "It's turning water that is a waste material into an asset." *—Johnna Rizzo*



Gowanus Canal Watershed

Watershed area

Sewer-shed area



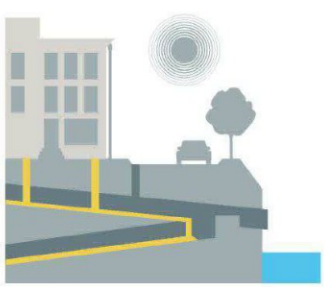
SEWAGE FOOTPRINT
The Gowanus Canal drains nearly three square miles of watershed. Sewage from an overlapping area almost the same size (right) feeds into two waste treatment plants nearby.

SHARED SEWER PIPES
The Gowanus area has a combined sewer system—one pipe for both sewage and rainwater. In dry weather (below, left) sewage travels to the waste treatment facility. During a storm (below, right) the combined volume can cause overload, and the extra flows into the canal.

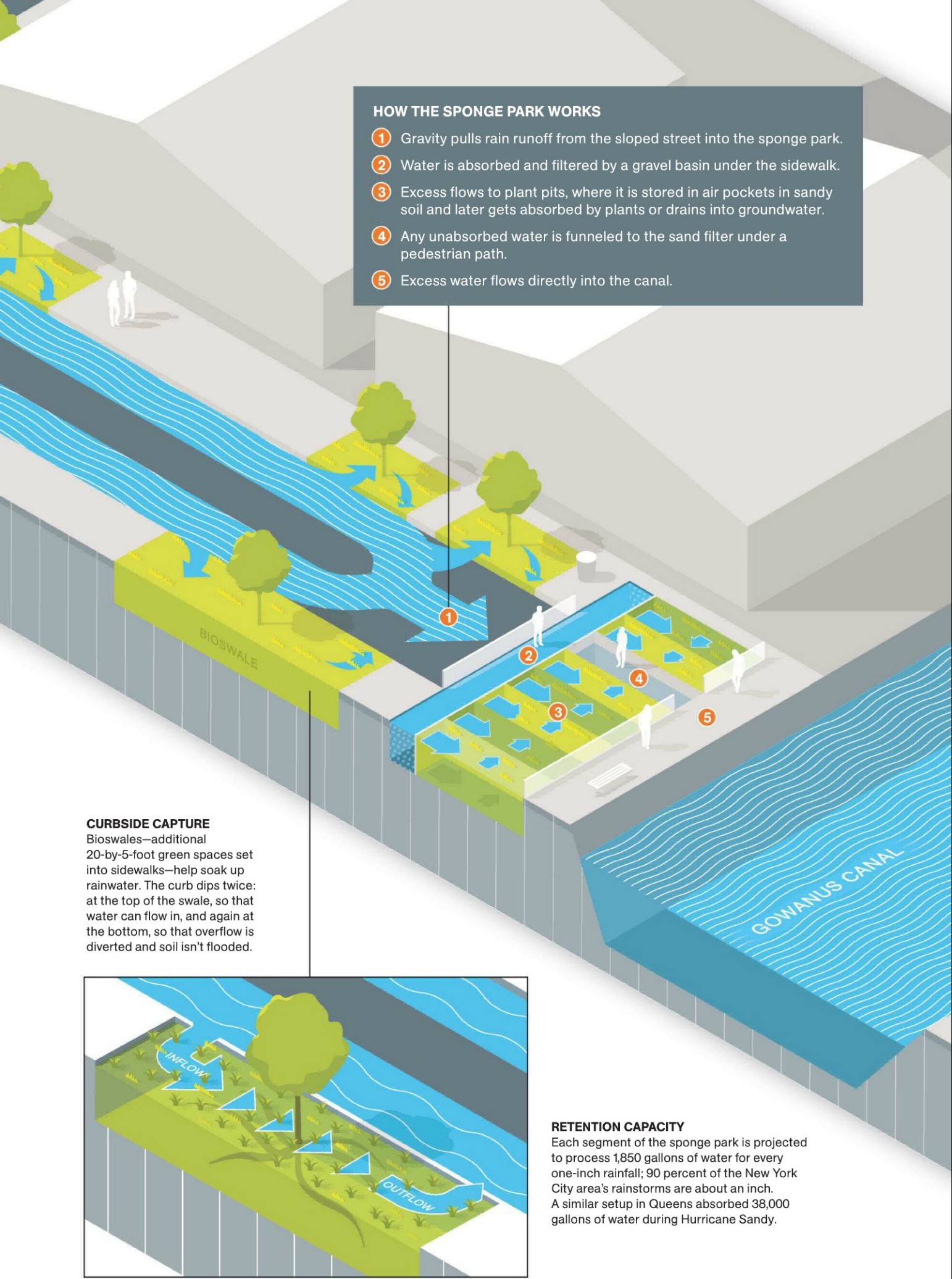
Sewage

Rainfall

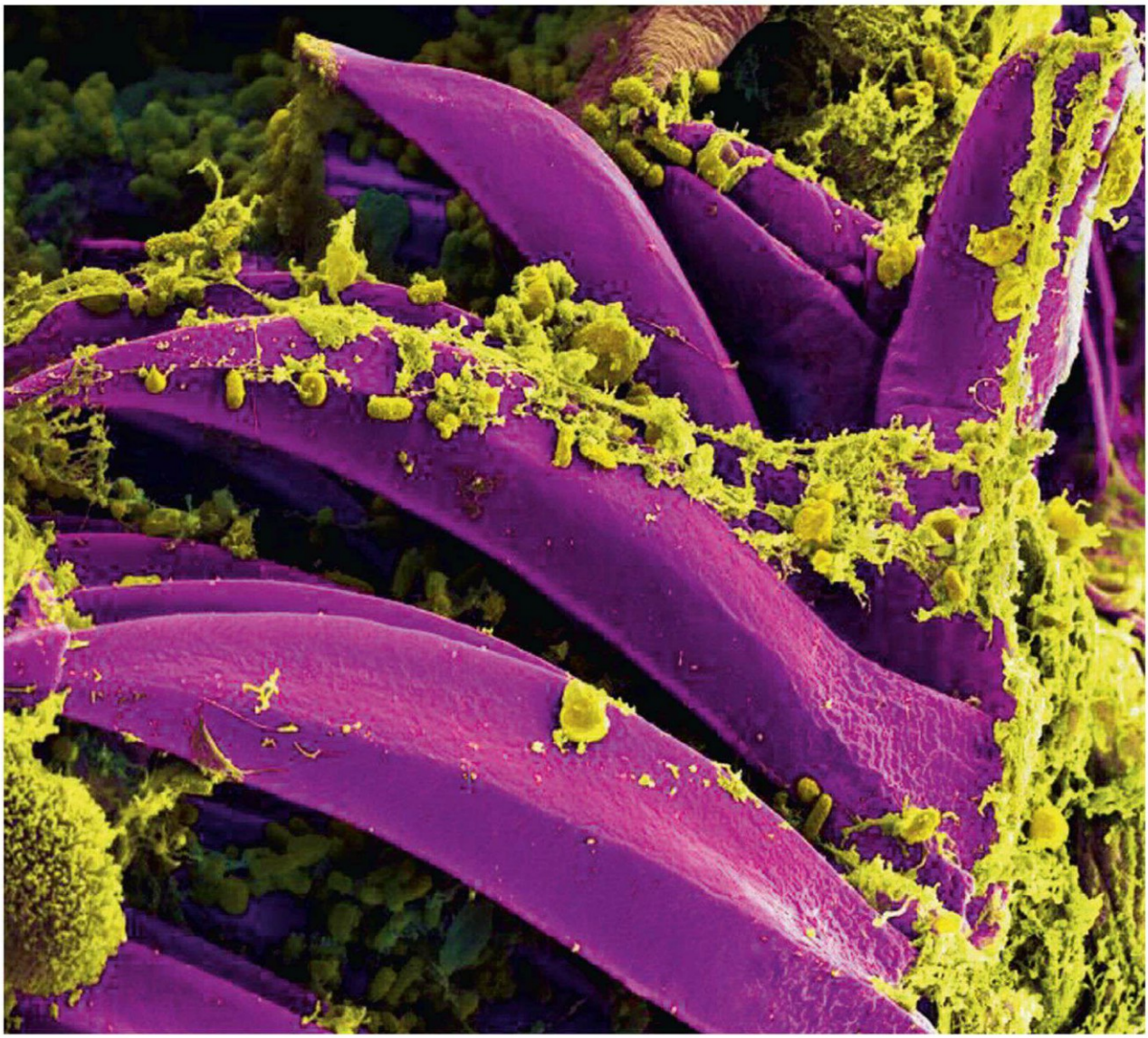
Sewage/ rainfall mix







JASON TREAT, NGM STAFF. GRAPHIC: THOMAS POROSTOCKY
SOURCES: SUSANNAH DRAKE, DLANDSTUDIO; NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION



Plague Persistence

The Black Death isn't a thing of the past. In 20 years there have been as many as 5,000 cases of plague, resulting in 100 to 200 reported deaths a year. In 2013 it persists on the Centers for Disease Control and Prevention's list of reemerging diseases. "We're not likely to have a big outbreak, but it's percolating in rodent communities," says CDC's Ken Gage.

When those rodents die—say, nestled in the thatched roof of a mud house in Uganda or at a campground in Colorado—their infected fleas can end up on people nearby. Eastern African nations are hardest hit, but cases can happen in any semiarid region when human and rodent populations mix. Unlike in historical epidemics, though, the plague isn't a death sentence today: Antibiotics cure it, but timely treatment is critical. Says Gage, "If not diagnosed within four or five days, the prognosis can be pretty grim." *—Johnna Rizzo*

Plague bacteria Yersinia pestis *(colorized image above) darken a rat flea's gut (below). If the flea bites, the plague washes into the wound.*



PHOTOS: NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES/SCIENCE SOURCE (TOP); CDC

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VAULT CODE: NG19-158

The world's largest organism is the fungus *Armillaria ostoyae,* one of which covers 2,384 acres in Oregon's Blue Mountains.

Beach Bumming

The bigger a beach, the more tourists' towels to fit on it—and the more money, in turn, for local business. That calculation can be complicated by erosion. Unwilling to build seawalls that, among other things, prevent beachgoers from enjoying waves, cities in Hawaii and North Carolina periodically renourish their beaches. The process involves dredging millions of cubic yards of sand offshore and depositing it on land.

More cities are investing in the method, according to the Army Corps of Engineers. Yet considering constant wave motion, the replenishment is often only temporary. Last fall the San Diego area fortified five miles of its coast at a cost of $28 million. Project managers say they'll need to do it again in about five years. *—Daniel Stone*

Portions of the shore in Virginia Beach, Virginia, have been rebuilt 49 times since 1951.

Night Shift **For some people shortened day lengths bring on the blues. For rats it's the opposite. Neurobiologist Davide Dulcis found that when rodents are exposed to prolonged periods of light, their dopamine production gets thrown off. A chemical switch occurs, says Dulcis, that creates "depressive-like behaviors in the animals." Since rats and humans have similarly structured brains, the research could help scientists better understand dopamine-related illnesses, including Parkinson's and schizophrenia.** ***—Catherine Zuckerman***

PHOTO: GEORGE STEINMETZ. GRAPHIC: MESA SCHUMACHER. ART: MARC JOHNS

SWISS DECLARE WAR ON US

Watchmakers are FURIOUS and luxury brands are LIVID, but WHO CARES? We made this $99 Swiss watch for YOU!

How dare Stauer break the unwritten rule in Switzerland? Chaos erupted at this year's Basel watch fair. The watchmaking elite attacked me in French, German and Italian (with the occasional British accent), outraged that Stauer would engineer a luxury Swiss-made timepiece for under $100. They said it couldn't be done, but we did it anyway. Now you get to wear the spectacular Swiss-Made ***Stauer Bienne*** for **ONLY $99!**

Join the luxury revolution. The crown princes of watchmaking worried that their exorbitant yacht vacations in Monaco would be in jeopardy. For years they convinced the world that Swiss luxury should cost THOUSANDS. But in reality, those thousands went to Swiss bank accounts, six-figure supermodels and ski chalets and NOT into the engineering of the watches. Shame on them. It's time for a change. You deserve it.

You CAN own an exquisitely engineered Swiss timepiece for under $100. The only thing that matters is the machine, so we went to the factory in Bienne and met with Francois, a fourth generation watchbuilder who makes masterpieces that sell for $5,000 and more. Working together we smashed the once unbreakable $100 barrier. The shockwaves have turned the luxury watch world upside-down. That's why the Swiss declared war on us. We consider it a compliment.

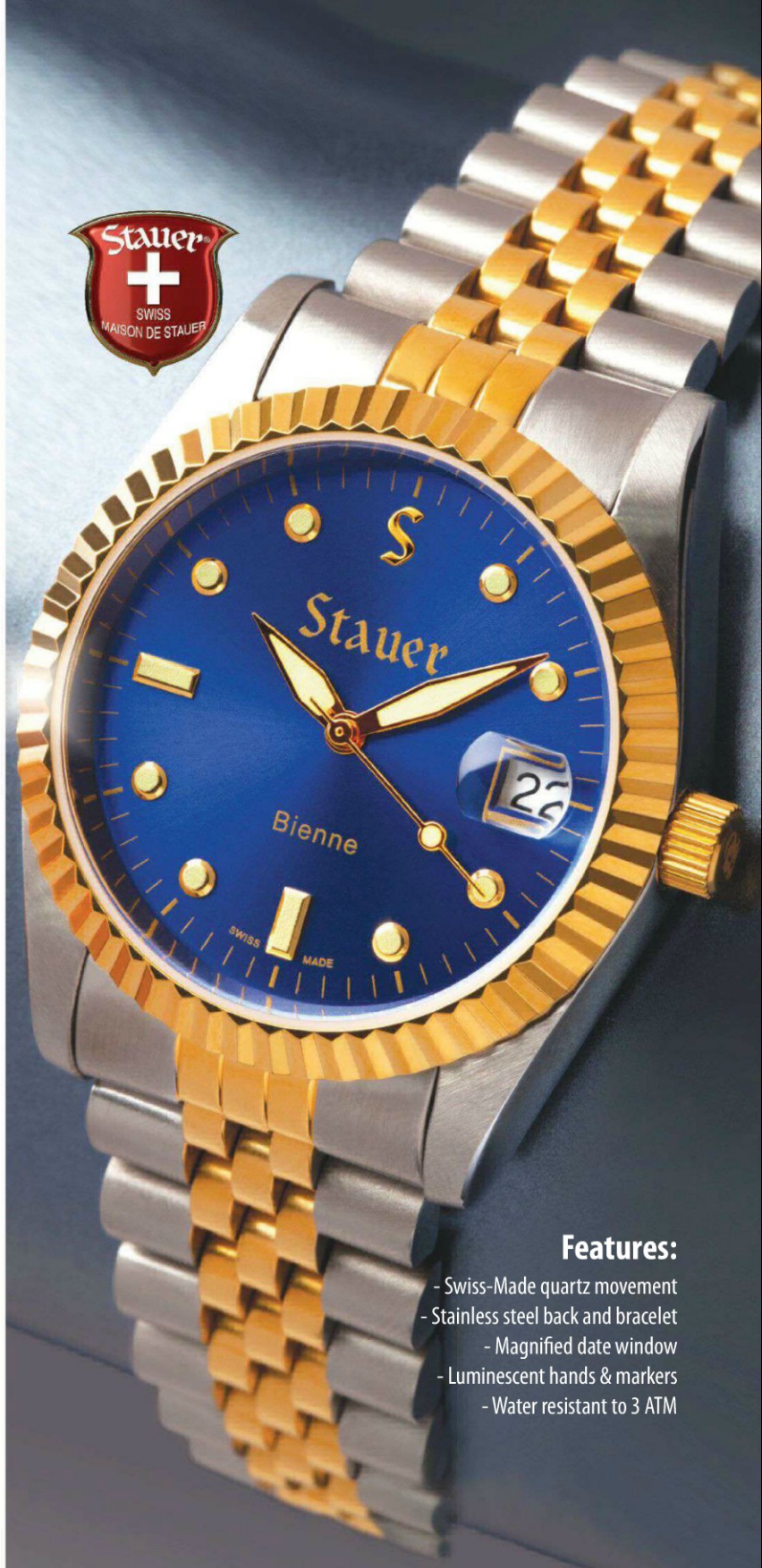
The industry cursed me but the buyers were thrilled. It was like the walls came down and watch lovers were set free. The cabal was broken. Now everyone can experience the cachet of a genuine Swiss timepiece. Next I'll begin work on the 20-room mansion for $30,000 and an Italian sports car for $3,300. How about a private jet for $12,000? If we can break the Swiss price by this much, who knows what's next?

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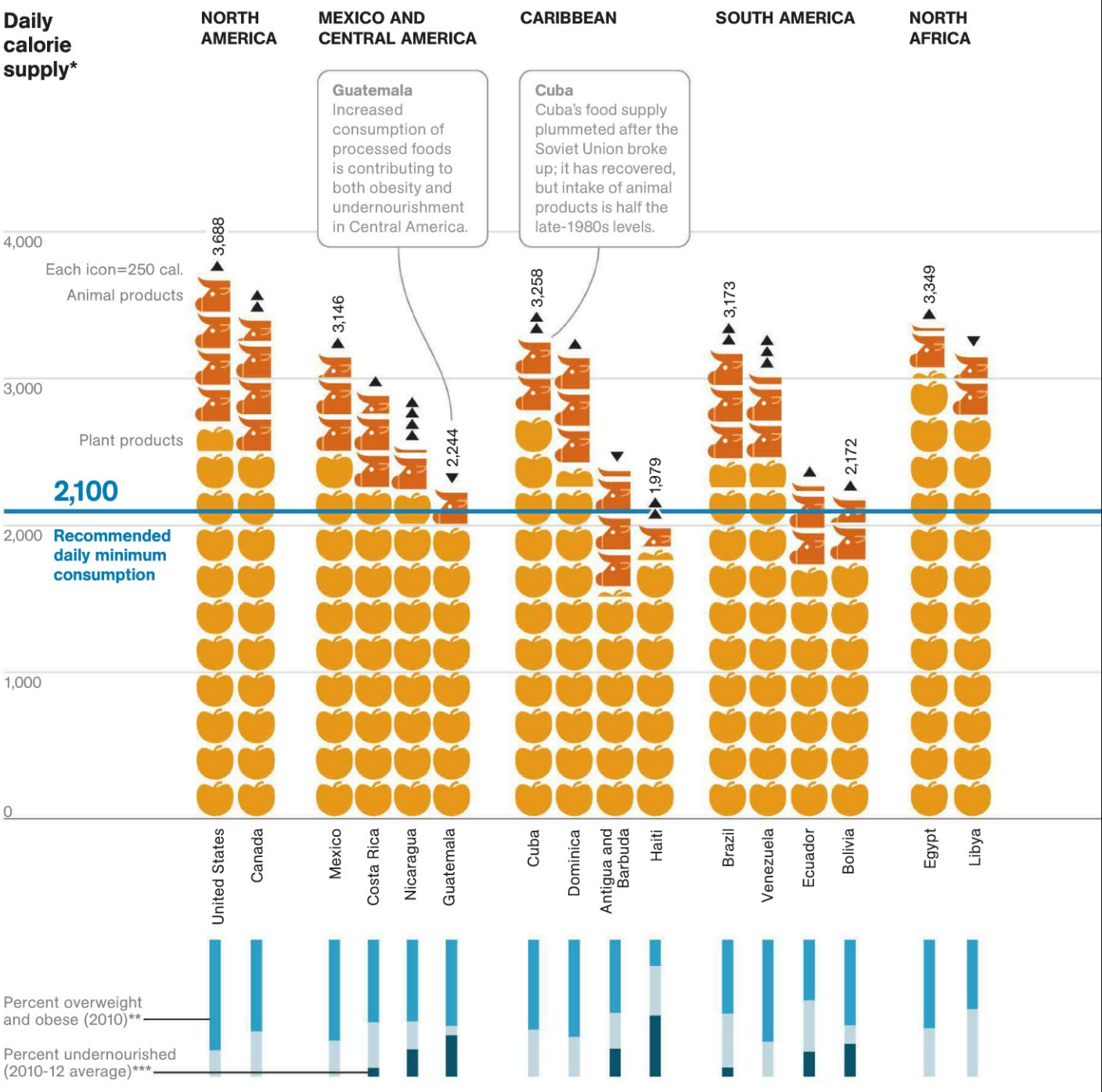
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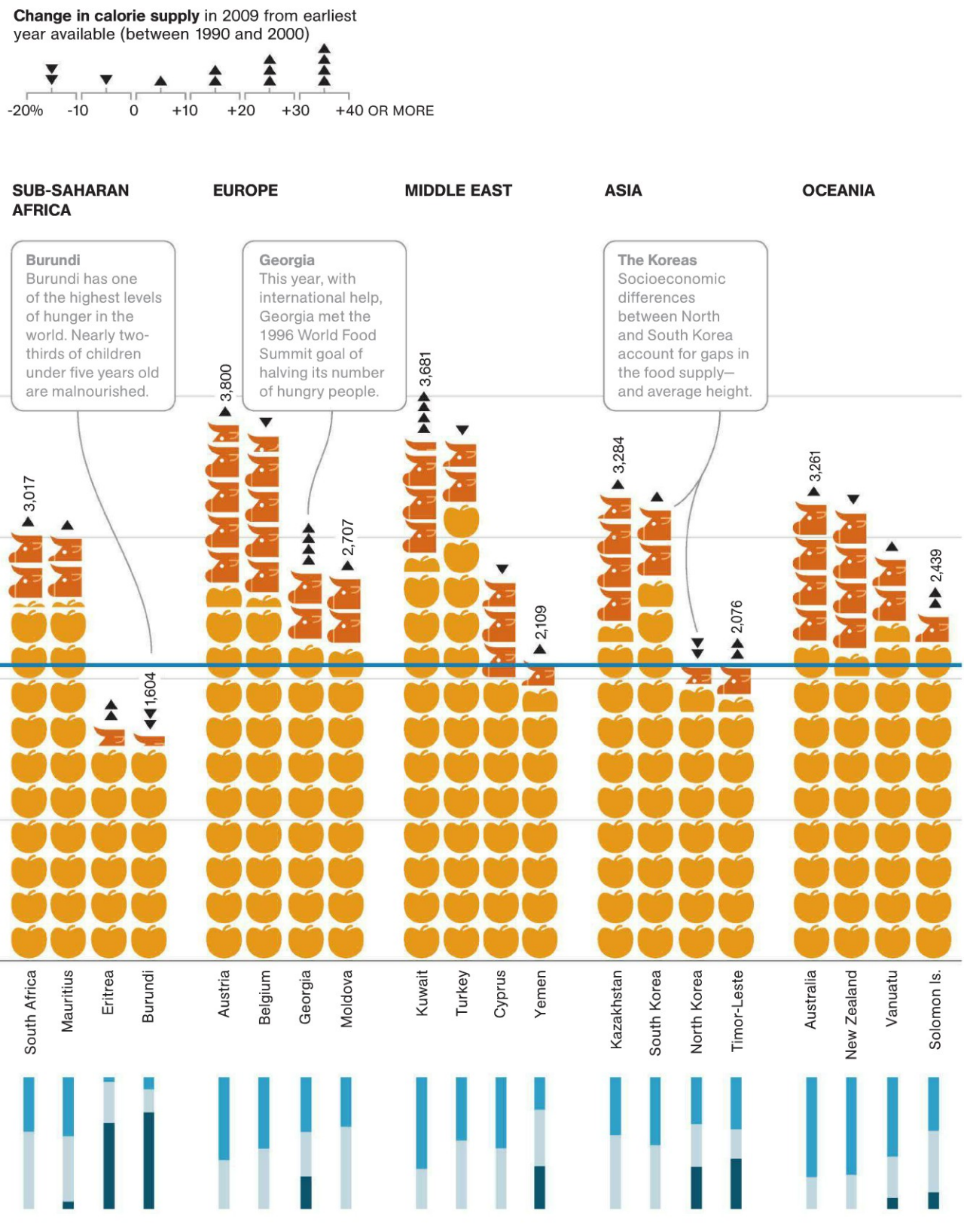
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Rating of A+

Counting Calories

Worldwide, average daily food supply per person has steadily increased from 2,200 to 2,800 calories over the past 50 years, due primarily to advances in agriculture. This trend has had a dual effect, decreasing undernourishment rates in many developing nations while enlarging belt sizes in all regions. According to the UN Food and Agriculture Organization (FAO), global consumption of sugar, salt, and saturated fats is expected to grow. Whether food is abundant or scarce, it seems, calories count. *—Kelsey Nowakowski*



* Estimate of the per capita amount of food calories available for human consumption
** Males age 15 and above
*** Proportion of the population suffering from food deprivation



GRAPHIC: ÁLVARO VALIÑO. SOURCES: UN FOOD AND AGRICULTURE ORGANIZATION; WORLD HEALTH ORGANIZATION



Grouse and Home

A male Gunnison sage-grouse is a flashy fellow—puffing air into golden sacs on his chest, then waggling them to elicit a distinctive popping sound meant to attract females. Procreation may be becoming increasingly important for the species, identified in 2000. In 2013 it numbers fewer than 5,000, and the process for inclusion on the U.S. endangered species list has begun. Some contend the label may not be a good thing. The U.S. Fish and Wildlife Service cites roads, livestock grazing, and invasive plants as perilous encroachments on habitat and sagebrush, a sage-grouse's primary food source. Colorado Parks and Wildlife is challenging the designation, asserting 62,000 acres of protected sage fields and rising numbers of males in core habitat breeding grounds. *—Johnna Rizzo*





Bacteria to Go

The upside of reusable bags is that they limit plastic waste. The downside, studies have shown, is that users rarely wash them. That leads to a buildup of bacteria caused by carrying things like raw meat, rotten fruit, or dirty clothes. In cities such as San Francisco that have promoted reusable bags by banning plastic ones, illnesses from bacteria spiked, a team of economics researchers found. Later analysis revealed 12 percent of bags even contained *E. coli.* An easy fix: Hot water and soap reduced bacteria to almost zero. *—Daniel Stone*

PHOTOS: GERRIT VYN (TOP); REBECCA HALE, NGM STAFF
NGM MAPS. SOURCES: COLORADO PARKS AND WILDLIFE; UTAH DIVISION OF WILDLIFE RESOURCES



For patients 12 years and older whose asthma is not well controlled on a long-term asthma medicine or whose disease severity warrants

IF YOU THINK ASTHMA 'COMES AND GOES'

THINK AGAIN.

IT'S MISUNDERSTOOD. ASTHMA DOESN'T COME AND GO. Inflammation, the root cause of asthma is always there, making your lungs more vulnerable to triggers. So, while it's important to avoid triggers, it's also important to treat this inflammation. SYMBICORT helps reduce the underlying inflammation. SYMBICORT helps keep airways open and improve lung function for better breathing all day and night.* SYMBICORT does not replace a rescue inhaler for sudden symptoms. Once your asthma is well controlled, your doctor will decide if you can stop taking SYMBICORT without loss of control and may prescribe a long-term asthma control medicine such as an inhaled corticosteroid.

* When taken twice daily.

Ask your doctor about SYMBICORT.

IMPORTANT INFORMATION ABOUT SYMBICORT

Important Safety Information About SYMBICORT for Asthma

SYMBICORT contains formoterol, a long-acting beta$_2$-adrenergic agonist (LABA). LABA medicines such as formoterol increase the risk of death from asthma problems. It is not known whether budesonide, the other medicine in SYMBICORT, reduces the risk of death from asthma problems seen with formoterol. SYMBICORT should be used only if your health care provider decides that your asthma is not well controlled with a long-term asthma control medicine, such as an inhaled corticosteroid, or that your asthma is severe enough to begin treatment with SYMBICORT.

If you are taking SYMBICORT, see your health care provider if your asthma does not improve or gets worse. It is important that your health care provider assess your asthma control on a regular basis. Your doctor will decide if it is possible for you to stop taking SYMBICORT and start taking a long-term asthma control medicine without loss of asthma control. Children and adolescents who take LABA medicines may have an increased risk of being hospitalized for asthma problems.

SYMBICORT does not replace rescue inhalers for sudden asthma symptoms.

Be sure to tell your health care provider about all your health conditions, including heart conditions or high blood pressure, and all medicines you may be taking. Some patients taking SYMBICORT may experience increased blood pressure, heart rate, or change in heart rhythm.

Do not use SYMBICORT more often than prescribed. While taking SYMBICORT, never use another medicine containing a LABA for any reason. Ask your health care provider or pharmacist if any of your other medicines are LABA medicines, as using too much LABA may cause chest pain, increase in blood pressure, fast and irregular heartbeat, headache, tremor, and nervousness.

Patients taking SYMBICORT should call their health care provider or get emergency medical care:

- if you experience serious allergic reactions including rash, hives, swelling of the face, mouth and tongue, and breathing problems.
- if you think you are exposed to infections such as chicken pox or measles, or if you have any signs of infection. You may have a higher chance of infection.
- if you experience an increase in wheezing right after taking SYMBICORT, eye problems including glaucoma and cataracts, decreases in bone mineral density, swelling of blood vessels (signs include a feeling of pins and needles or numbness of arms or legs, flu like symptoms, rash, pain and swelling of the sinuses), decrease in blood potassium and increase in blood sugar levels.

If you are switching to SYMBICORT from an oral corticosteroid, follow your health care provider's instructions to avoid serious health risks when you stop using oral corticosteroids. Common side effects include nose and throat irritation, headache, upper respiratory tract infection, sore throat, sinusitis, stomach discomfort, flu, back pain, nasal congestion, vomiting, and thrush in the mouth and throat.

Approved Uses for SYMBICORT for Asthma

SYMBICORT is a medicine for the treatment of asthma for people 12 years and older whose doctor has determined that their asthma is not well controlled with a long term asthma control medicine such as an inhaled corticosteroid or whose asthma is severe enough to begin treatment with SYMBICORT. SYMBICORT is not a treatment for sudden asthma symptoms.

Please see Important Product Information on adjacent page and discuss with your doctor.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

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† Subject to eligibility rules. Restrictions apply.

For more information, call 1-866-SYMBICORT or go to MySymbicort.com

If you're without prescription coverage and can't afford your medication, AstraZeneca may be able to help. For more information, please visit www.astrazeneca-us.com

Symbicort®
(budesonide/formoterol fumarate dihydrate)
Inhalation Aerosol

AstraZeneca

IMPORTANT INFORMATION ABOUT SYMBICORT

Please read this summary carefully and then ask your doctor about SYMBICORT.

No advertisement can provide all the information needed to determine if a drug is right for you or take the place of careful discussions with your health care provider. Only your health care provider has the training to weigh the risks and benefits of a prescription drug.

WHAT IS THE MOST IMPORTANT INFORMATION I SHOULD KNOW ABOUT SYMBICORT?

People with asthma who take long-acting beta$_2$-agonist (LABA) medicines, such as formoterol (one of the medicines in SYMBICORT), have an increased risk of death from asthma problems. It is not known whether budesonide, the other medicine in SYMBICORT, reduces the risk of death from asthma problems seen with formoterol.

SYMBICORT should be used only if your health care provider decides that your asthma is not well controlled with a long-term asthma control medicine, such as an inhaled corticosteroid, or that your asthma is severe enough to begin treatment with SYMBICORT. Talk with your health care provider about this risk and the benefits of treating your asthma with SYMBICORT.

If you are taking SYMBICORT, see your health care provider if your asthma does not improve or gets worse. It is important that your health care provider assess your asthma control on a regular basis. Your doctor will decide if it is possible for you to stop taking SYMBICORT and start taking a long-term asthma control medicine without loss of asthma control.

Get emergency medical care if:

- breathing problems worsen quickly, and
- you use your rescue inhaler medicine, but it does not relieve your breathing problems.

Children and adolescents who take LABA medicines may be at increased risk of being hospitalized for asthma problems.

WHAT IS SYMBICORT?

SYMBICORT is an inhaled prescription medicine used for asthma and chronic obstructive pulmonary disease (COPD). It contains two medicines:

- Budesonide (the same medicine found in Pulmicort Flexhaler™, an inhaled corticosteroid). Inhaled corticosteroids help to decrease inflammation in the lungs. Inflammation in the lungs can lead to asthma symptoms
- Formoterol (the same medicine found in Foradil® Aerolizer®). LABA medicines are used in patients with COPD and asthma to help the muscles in the airways of your lungs stay relaxed to prevent asthma symptoms, such as wheezing and shortness of breath. These symptoms can happen when the muscles in the airways tighten. This makes it hard to breathe, which, in severe cases, can cause breathing to stop completely if not treated right away

SYMBICORT is used for asthma and chronic obstructive pulmonary disease as follows:

Asthma

SYMBICORT is used to control symptoms of asthma and prevent symptoms such as wheezing in adults and children ages 12 and older.

Chronic Obstructive Pulmonary Disease

COPD is a chronic lung disease that includes chronic bronchitis, emphysema, or both. SYMBICORT 160/4.5 mcg is used long term, two times each day, to help improve lung function for better breathing in adults with COPD.

WHO SHOULD NOT USE SYMBICORT?

Do not use SYMBICORT to treat sudden severe symptoms of asthma or COPD or if you are allergic to any of the ingredients in SYMBICORT.

WHAT SHOULD I TELL MY HEALTH CARE PROVIDER BEFORE USING SYMBICORT?

Tell your health care provider about all of your health conditions, including if you:

- have heart problems
- have high blood pressure
- have seizures
- have thyroid problems
- have diabetes
- have liver problems
- have osteoporosis
- have an immune system problem
- have eye problems such as increased pressure in the eye, glaucoma, or cataracts
- are allergic to any medicines
- are exposed to chicken pox or measles
- **are pregnant or planning to become pregnant.** It is not known if SYMBICORT may harm your unborn baby
- **are breast-feeding.** Budesonide, one of the active ingredients in SYMBICORT, passes into breast milk. You and your health care provider should decide if you will take SYMBICORT while breast-feeding

Tell your health care provider about all the medicines you take including prescription and nonprescription medicines, vitamins, and herbal supplements. SYMBICORT and certain other medicines may interact with each other and can cause serious side effects. Know all the medicines you take. Keep a list and show it to your health care provider and pharmacist each time you get a new medicine.

HOW DO I USE SYMBICORT?

Do not use SYMBICORT unless your health care provider has taught you and you understand everything. Ask your health care provider or pharmacist if you have any questions.

Use SYMBICORT exactly as prescribed. **Do not use SYMBICORT more often than prescribed.** SYMBICORT comes in two strengths for asthma: 80/4.5 mcg and 160/4.5 mcg. Your health care provider will prescribe the strength that is best for you. SYMBICORT 160/4.5 mcg is the approved dosage for COPD.

- SYMBICORT should be taken every day as 2 puffs in the morning and 2 puffs in the evening.
- Rinse your mouth with water and spit the water out after each dose (2 puffs) of SYMBICORT. This will help lessen the chance of getting a fungus infection (thrush) in the mouth and throat.
- Do not spray SYMBICORT in your eyes. If you accidentally get SYMBICORT in your eyes, rinse your eyes with water. If redness or irritation persists, call your health care provider.
- Do not change or stop any medicines used to control or treat your breathing problems. Your health care provider will change your medicines as needed
- **While you are using SYMBICORT 2 times each day, do not use other medicines that contain a long-acting beta$_2$-agonist (LABA) for any reason. Ask your health care provider or pharmacist if any of your other medicines are LABA medicines.**
- SYMBICORT does not relieve sudden symptoms. Always have a rescue inhaler medicine with you to treat sudden symptoms. If you do not have a rescue inhaler, call your health care provider to have one prescribed for you.

Call your health care provider or get medical care right away if:

- your breathing problems worsen with SYMBICORT
- you need to use your rescue inhaler medicine more often than usual
- your rescue inhaler does not work as well for you at relieving symptoms
- you need to use 4 or more inhalations of your rescue inhaler medicine for 2 or more days in a row
- you use one whole canister of your rescue inhaler medicine in 8 weeks' time
- your peak flow meter results decrease. Your health care provider will tell you the numbers that are right for you
- your symptoms do not improve after using SYMBICORT regularly for 1 week

WHAT MEDICATIONS SHOULD I NOT TAKE WHEN USING SYMBICORT?

While you are using SYMBICORT, do not use other medicines that contain a long-acting beta$_2$-agonist (LABA) for any reason, such as:

- Serevent® Diskus® (salmeterol xinafoate inhalation powder)
- Advair Diskus® or Advair® HFA (fluticasone propionate and salmeterol)
- Formoterol-containing products such as Foradil Aerolizer, Brovana®, or Perforomist®

WHAT ARE THE POSSIBLE SIDE EFFECTS WITH SYMBICORT?

SYMBICORT can cause serious side effects.

- Increased risk of pneumonia and other lower respiratory tract infections if you have COPD. Call your health care provider if you notice any of these symptoms: increase in mucus production, change in mucus color, fever, chills, increased cough, increased breathing problems
- Serious allergic reactions including rash; hives; swelling of the face, mouth and tongue; and breathing problems. Call your health care provider or get emergency care if you get any of these symptoms
- Immune system effects and a higher chance for infections
- Adrenal insufficiency–a condition in which the adrenal glands do not make enough steroid hormones
- Cardiovascular and central nervous system effects of LABAs, such as chest pain, increased blood pressure, fast or irregular heartbeat, tremor, or nervousness
- Increased wheezing right after taking SYMBICORT
- Eye problems, including glaucoma and cataracts. You should have regular eye exams while using SYMBICORT
- Osteoporosis. People at risk for increased bone loss may have a greater risk with SYMBICORT
- Slowed growth in children. As a result, growth should be carefully monitored
- Swelling of your blood vessels. This can happen in people with asthma
- Decreases in blood potassium levels and increases in blood sugar levels

WHAT ARE COMMON SIDE EFFECTS OF SYMBICORT?

Patients with Asthma

Sore throat, headache, upper respiratory tract infection, thrush in the mouth and throat

Patients with COPD

Thrush in the mouth and throat

These are not all the side effects with SYMBICORT. Ask your health care provider or pharmacist for more information.

NOTE: This summary provides important information about SYMBICORT. For more information, please ask your doctor or health care provider.

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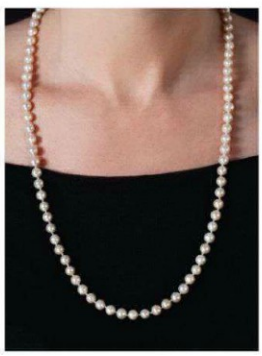


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Vatican City has 572 passport holders, one woman to every 17 men.



Shell Life

All vertebrate embryos look similar, at least at the start of gestation. After about 16 days of development, though, a turtle makes some radical adjustments. Its shoulder bones slide inside its rib cage, making room for the shell to grow. Then its ribs move out and up, eventually fusing to help form the back half of its shell, a part of its exoskeleton called a carapace. Turtles are among the few vertebrates that have an exoskeleton; in many it's substantial enough to make up about a third of their body weight.

A genome sequencing of the Chinese soft-shelled turtle (left) and green sea turtle, completed by biologist Naoki Irie's team, revealed what may make the shell materialize. Part of the mechanism used to form limbs gets co-opted to develop the shell. Next Irie plans to look into why turtle development hasn't created a shortcut in the past 250 million years. "Why don't they grow their shoulders inside the rib cage from the beginning?" says Irie. "They are taking a winding path, evolutionarily speaking. It's a mystery." *—Johnna Rizzo*



At about 16 days, turtle embryos begin to grow a shell.

ET CETERA

Some mosquitoes may be immune to the repellent effects of **DEET** after the first exposure, London entomologists found. ▪ Archaeologists located the 1,200-year-old city of **MAHENDRAPARVATA** in the Cambodian jungle using laser radar technology. ▪ **HIGH-GLYCEMIC FOODS** like white bread and instant oatmeal may be addictive, a U.S. study suggested. ▪ Scientists showed that fat stored in the livers of **GREAT WHITE SHARKS** helps retain energy, allowing them to swim continuously for 2,000 miles.

PHOTOS: NAOKI IRIE, UNIVERSITY OF TOKYO. GRAPHIC: ÁLVARO VALIÑO

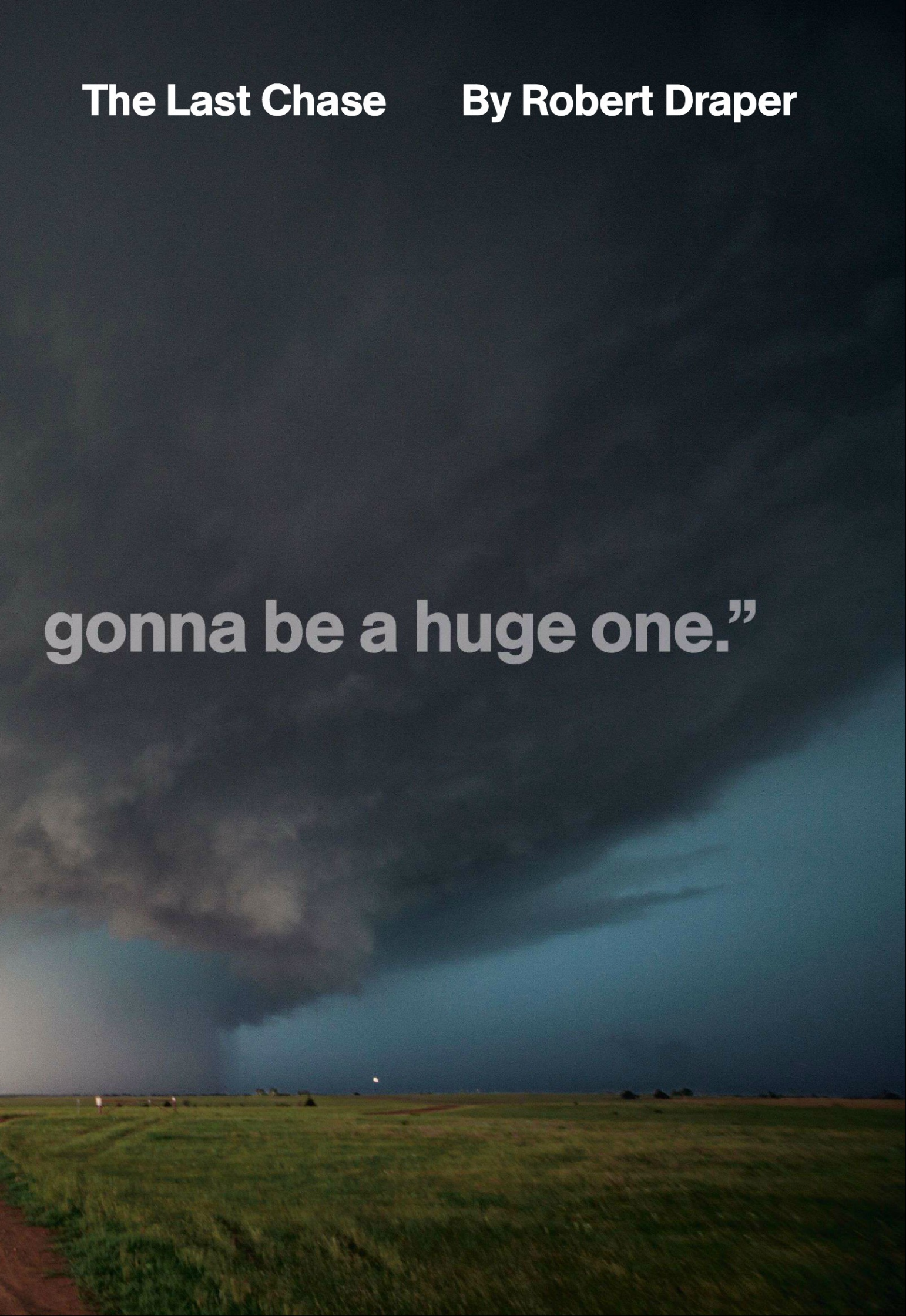


5:51 P.M., MAY 31, 2013 | EL RENO, OKLAHOMA

"Oh, my God. This is

The Last Chase

By Robert Draper





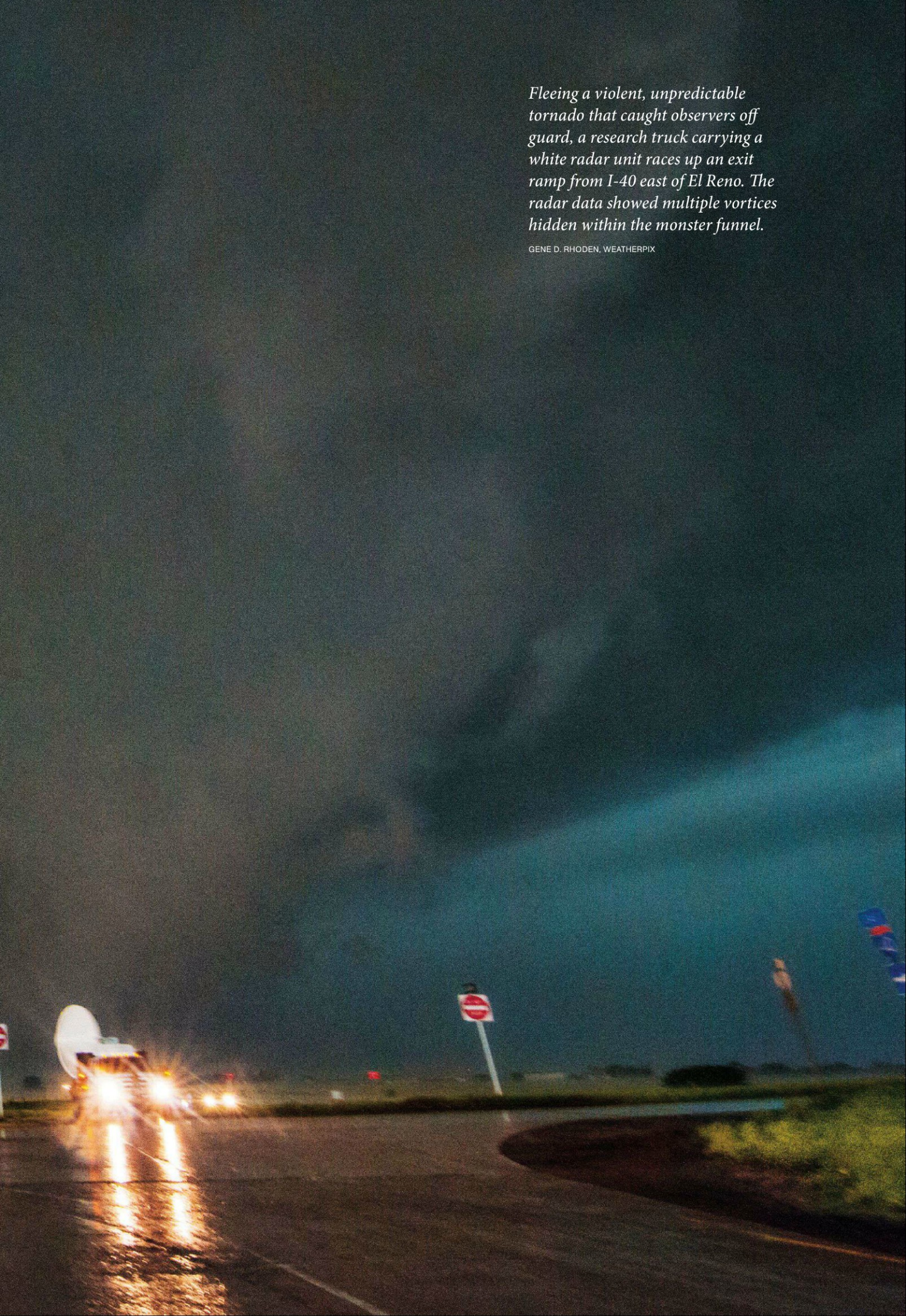


GREGORY KÄSER WITH MARKUS PFISTER (ALL)


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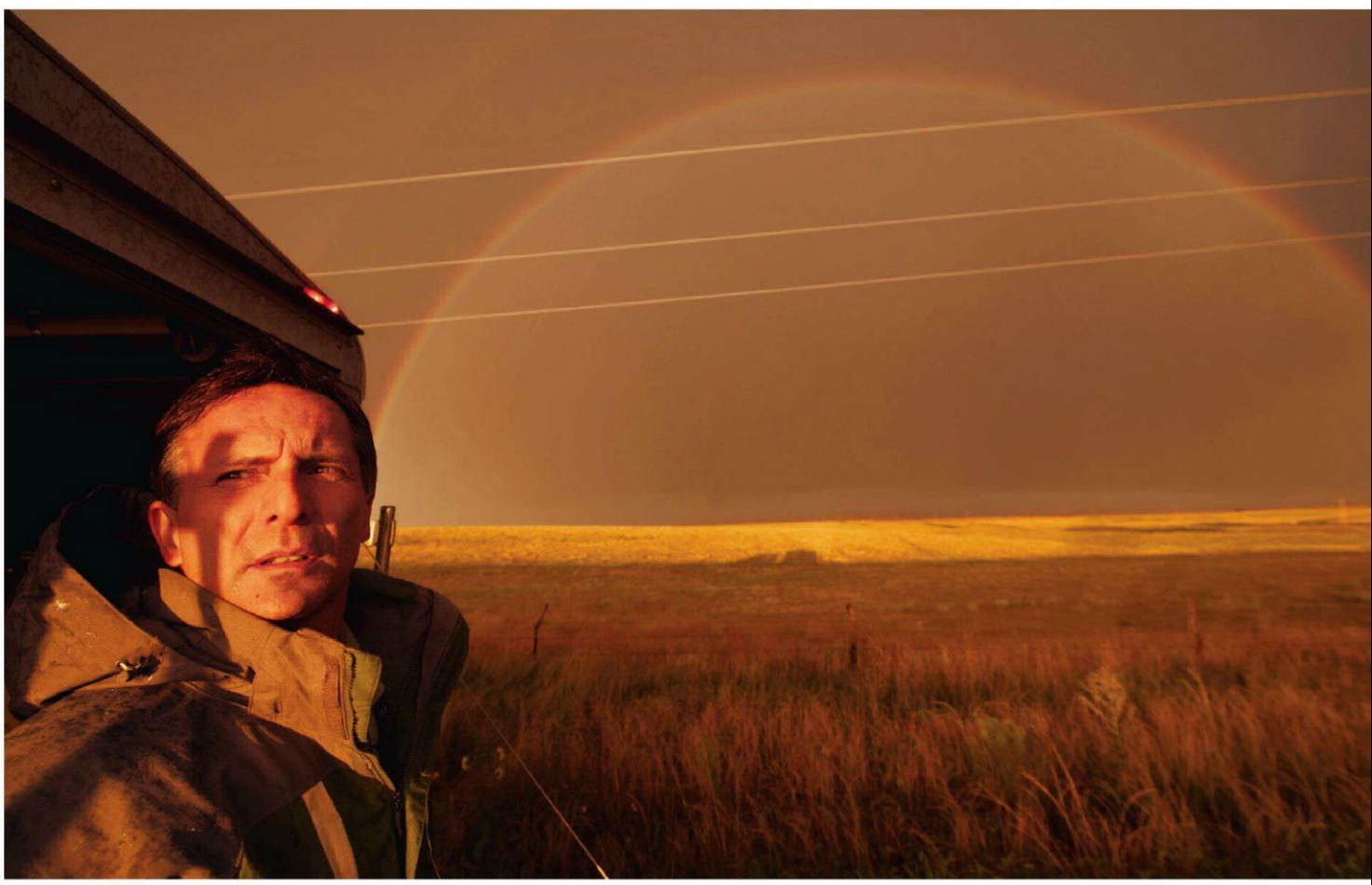

6:05 P.M.


6:26 P.M.



Fleeing a violent, unpredictable tornado that caught observers off guard, a research truck carrying a white radar unit races up an exit ramp from I-40 east of El Reno. The radar data showed multiple vortices hidden within the monster funnel.

GENE D. RHODEN, WEATHERPIX



Celebrated storm chaser and scientist Tim Samaras pursued tornadoes with single-minded passion. The quest to understand what went on inside them and on the ground under them took him far and wide and finally one evening on a fateful visit to a muddy Oklahoma farm road.

CARSTEN PETER; PHOTO TAKEN IN COLORADO IN AUGUST 2009

It's shortly after six in the evening on May 31, 2013. Sitting in the passenger seat of the white Chevrolet Cobalt, the 55-year-old, bookishly handsome storm chaser momentarily gapes at the video camera that the driver of the car is pointing at his face. Then he looks back through the window at the outskirts of El Reno, Oklahoma. The wheat fields are eerily aglow and shudder from a vicious wind. No more than two miles away from the car, twin funnel clouds spiral downward from an immensity of blackness. What we hear in the man's voice on the videotape is not quite terror. Nor, however, do his words sound clinically factual, in the manner of the scientist he happens to be.

"Oh, my God. This is gonna be a huge one," he says.

The man frowns. He strokes his chin with almost comical vigor. His name is Tim Samaras, and much of his adult life has been spent in the dangerous company of tornadoes. He's obsessed with them, to be honest—to the point where his wife, Kathy, would wryly note that her husband "had an affair with Mother Nature."

The affair had resumed later than usual this spring. "Who ate all the tornadoes?" he complained via Twitter. And on Facebook: "Why can't there be wedges harmlessly roaming the open plains for us geeky chasers to observe?" But then the month that storm chasers refer to as May Magic arrived—and with it, vertical wind shear produced by southerly winds originating from the Gulf of Mexico lifting and cooling air moving east over the Rocky Mountains, thereby generating thunderstorms and, along the way, lighting up the online discussion groups of happy storm chasers all across America: Severe weather! Severely GREAT weather!

On the morning of May 18 Samaras kissed Kathy goodbye and made sure that his lucky McDonald's cheeseburger—an actual, if by now somewhat moldy, cheeseburger—was situated correctly on the dashboard of his Cobalt. Then

Samaras was asked to play a lead in a new series called *Storm Chasers*. It became a primary funding source for years. The Clark Kent-ish engineer was now a TV star.

he and two members of his crew—a 45-year-old meteorologist named Carl Young and Samaras's 24-year-old son, Paul—bolted eastward from their home in Bennett, Colorado, for the midwestern plains known as Tornado Alley, where his other love awaited.

The tornado that very evening in Rozel, Kansas, had been gorgeous, glowing tangerine against the sun while its long rope undulated like a belly dancer—and, thankfully, left Rozel largely unharmed in the process. "Wow, did you see that?" Tim said to a fellow storm chaser, Jeff Pietrowski, who would remember Samaras's jubilant expression. While logging thousands of miles over the next four days through Kansas, Oklahoma, and Texas, Samaras and his team, known as TWISTEX, would encounter at least 11 tornadoes. Then, after four nights back home, Samaras returned to the road, in a truck outfitted with a gargantuan high-speed camera for the purpose of conducting lightning research in Kansas—though, as he acknowledged in a Facebook posting, he was "bringing secondary vehicle for a 'side' of tornado chasing (I love sides)."

In the May 31 videotape Samaras sits in that secondary vehicle, the Cobalt, a storm chaser on yet another chase. A man in exuberant pursuit of his passion. And yet it could not be more apparent that something is different this time—maybe because the viewer knows something that Samaras does not.

"It's heading straight for Oklahoma City," he mutters.

The tornado is the progeny of several thunderstorms that developed along a cold front over central Oklahoma that afternoon. At just after 6 p.m. it dropped out of the tip of the southernmost supercell, where the warm and moist air was most prevalent. Now it is a dense, moist leviathan. It rotates counterclockwise in a crazed ballet across the klieg-lit plains. The trees in its path shake as if possessed by the devil. Unlike its exquisitely geometric counterpart in Rozel, El Reno's tornado is a black wedge of indistinct composition.

"OK, I'm gonna stop," says Young, who was filming the storm as he drove. "We'll get a great view of it. This good?"

The Cobalt comes to a halt. Samaras and Young climb out, along with Paul, who is peering through a different video lens. The three men stand at the edge of a gravel road and squint

against the rain. As they do, a third funnel coils out of the sky.

"Three vortices!" Young exclaims.

"Yep," says Samaras. When he turns back to the camera, he looks awed by what he is witnessing. "Wow. This is gonna be a gigantic wedge."

Young agrees. "It could be a very long-lived tornado. It could be on the ground for miles."

They return to the car a couple of minutes later and, with the windshield wipers flapping, silently press on eastward, the tornado lumbering along to their south. Lightning flickers across the dismal sky. Power lines swing madly about. The wedge grows and grows, blotting out all traces of the sun, darkening the three men in the car.

"It's violent," one of them says.

Stop the tape. Pause and consider: These were not men given to violence. They were not gratuitous thrill seekers or adrenaline junkies or even kamikaze researchers fulfilling martyrdom in the name of science. In particular, the legendary storm chaser, inventor, and National Geographic Explorer Tim Samaras was known for evangelizing about safety and for bringing an abundance of caution to his vocation. Though the decade-long mission he had assigned himself—placing measurement devices known as probes in a tornado's path, which necessarily entailed putting himself in the same path—was inherently high risk, he went to considerable lengths to mitigate the danger. He practiced deploying probes incessantly, always noting the time it took. He studied the day's weather patterns as if the lives of his crew depended on it. He gamed out escape routes. And even after all that, Samaras would not hesitate to abort a chase if the roads were poor or the tornado was too rain wrapped for its path to be discernible. "I can't tell you how often we didn't deploy because he said, 'Nope, this is too dangerous,'" recalls Tony Laubach, a member of the TWISTEX crew. "It was almost annoying at times. We'd say, 'C'mon, we can do this!' But he was very cautious."

How, then, to reconcile that widely acknowledged fact with the tragic events that would overtake the three men on May 31? Did the perfectionist fatally err? Or was the storm at El Reno simply a monster that defied all calculations?

If some of the answers are finally unknowable, that would be fitting, since mystery was, and is, the true object of the storm chase. How does a tornado occur? Over the past 40 years, with the development of Doppler and other advanced forms of radar, researchers have become increasingly adept at tracking the rotating storms known as supercells. They can measure the atmosphere's "convective available potential energy," or CAPE, to determine a supercell's intensity. And after the fact they can rank a tornado's sheer destructiveness using the Fujita or the later Enhanced Fujita scales—both named after the famed meteorologist Ted Fujita, who began his career measuring the damage done by the nuclear bombings of Hiroshima and Nagasaki. But, says Howard Bluestein, one of the reigning experts on the subject, "we simply don't understand exactly what distinguishes supercells that produce tornadoes from those that do not."

That basic riddle tantalized both the scientist and the boy in Tim Samaras. From the early days, when storm chasers relied on folding maps and sought out phone booths to receive weather updates, to pursue a tornado has been to brush against a glorious if destructive mystique. "For me, it was the total beauty of the storm itself," says David Hoadley, now a retired program analyst with the EPA who began chasing in 1956 and is therefore understood to be the founding father of the storm-chasing community. The very architecture of the storm, Hoadley goes on to say, is awe-inspiring: the coherency of a gathering system as moist, warm air bursts through a cap of colder air and creates an updraft and then a massive anvil; the pillowy mammatus clouds that congregate beneath the anvil; the cloud ribbons known as inflow bands that rush into the storm; the descent of a "wall cloud," which tends to prefigure a tornado; and the twirling and talonlike "hook echo," usually composed of hail, shredded debris, or small raindrops, that often announces the tornado's violent arrival. All of this seemingly out of nowhere, in a matter of minutes—"kind of like a magical machine," says Hoadley.

The men like Hoadley and Samaras who devote much of their lives to the pursuit of storms—and yes, the tribe is overwhelmingly male—have a scientific basis for doing so. Still, to chase a storm is also to chase innocence, romance, and immortality all at once. The sensation that comes from

Robert Draper's last story for the magazine was an essay on photography. Photographer Carsten Peter frequently went on assignment with Tim Samaras.





A Shared Passion

Moved by the fierce beauty of a supercell, Paul Samaras captures the scene on video from the roof of the chase truck. Carl Young (at center) and Tim Samaras also document the storm, near Kingfisher, Oklahoma, in March 2012. The team often drove 500 miles or more to be in the right place at the right time.

CARSTEN PETER

tracking a weather system mile after mile, from its seemingly innocuous and sunny genesis all the way to its sudden descent from the sky, is a primal experience, an axis where life and death conjoin.

"It's an adrenaline rush," storm chaser and Army veteran Erik Fox confesses. "You can feel the wind and the temperatures, hear the wind, smell the moisture in the air. You can feel winds coming out of the southeast at 25 to 40 miles per hour at the surface, and then higher up it's 70 miles per hour—and higher still, coming out of the west, at over 100 miles per hour. You've got that wind shear and 70-degree dew point indicating high humidity. You can feel all of this, and you know it's gonna be a big day."



Living the Dream

"Chasing was in his blood," a friend says of Young (right). "He was never not in a good mood out there." Trained as a meteorologist, Young had a knack for finding big storms. Paul Samaras (far right), who was a teenager when he joined his father in the field, had grown over the years into a talented photographer.

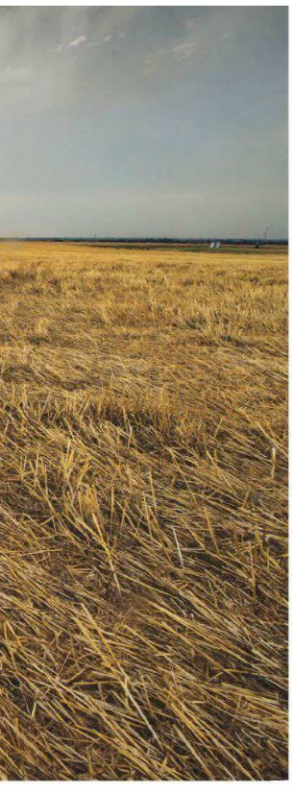
CARSTEN PETER (BOTH)

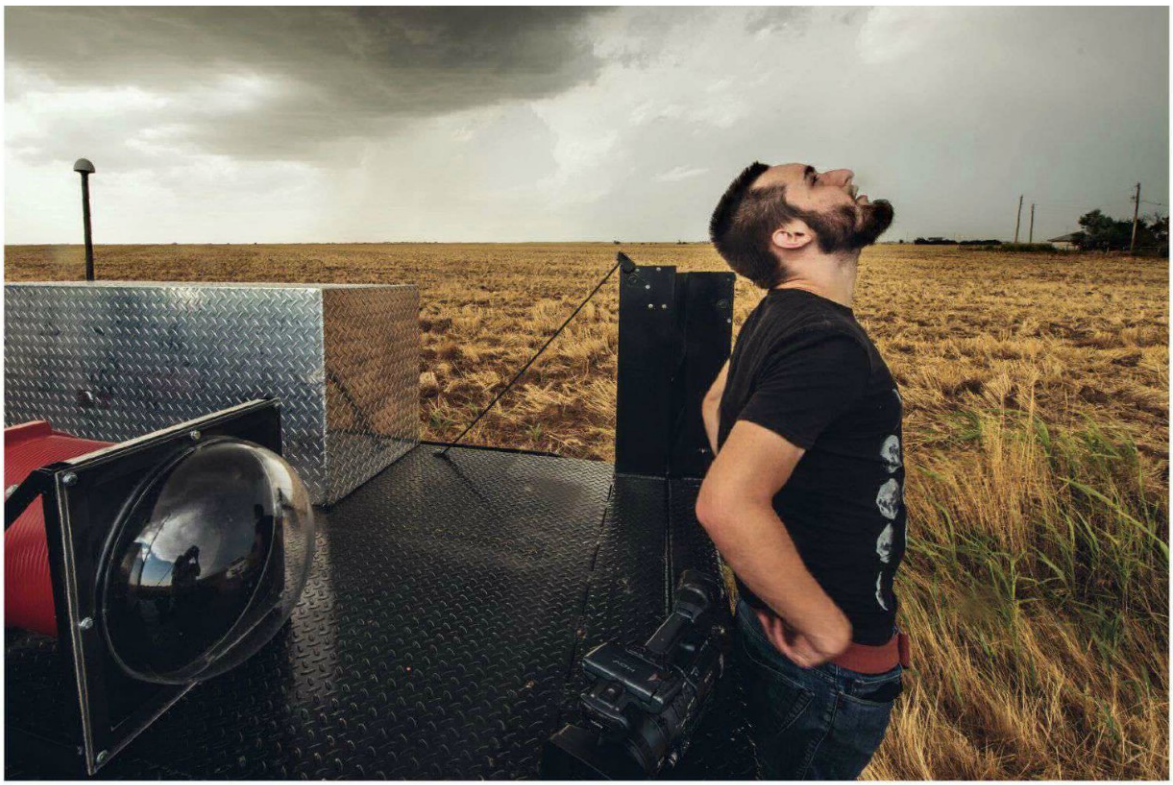
Though tornadoes are known to occur in such disparate locales as India, Australia, and the United Kingdom, they are fundamentally as American as baseball. The country's unique climate and topography produce more than a thousand tornadoes annually, far more than anywhere else. Nearly half of these occur in the Plains states during the spring. The weather geeks descend on Tornado Alley by the hundreds, arriving in vehicles tricked out with radios, mounted laptops, and cameras. Also accompanying them is a hope that springs eternal. It is not the modest aspiration to defy the 1-in-20 odds that a chased supercell will ultimately drop a tornado.

Rather it is the yearning to behold the incomparable beast that will join the holy litany of Big Ones, whose dates chasers lovingly recite like the birthdays of their children. May 24, 1973: the horrific tornado in Union City, Oklahoma, the first storm to be widely measured. April 26, 1991: the so-called Plains Tornado Outbreak that spawned 55 tornadoes and almost as many documentaries. May 4, 2007: the tornado that all but leveled Greensburg, Kansas. May 3, 1999: the savage Bridge Creek–Moore, Oklahoma, storm, about which atmospheric scientist and Doppler on Wheels inventor Joshua Wurman would dryly observe, "People who have experience in damage surveys are greatly impressed with the amount of damage that that particular tornado did."

Damage. In addition to its pleasing aesthetics—unpolluted skies, pastoral flatness, and fine, agrarian color contrast—Tornado Alley has the merciful feature of being sparsely populated. Still, the reality is unavoidable: The storm chaser who yearns for the sight of an epic tornado is inadvertently rooting for devastation. Crops and livestock are destroyed, farmhouses and barns shredded. The infamous Bridge Creek–Moore tornado left 36 dead; several of those who survived had been sprayed by flying dust and gravel with such force that their skin appeared to have been sandblasted. And on May 22, 2011, the EF5 (the highest possible Enhanced Fujita ranking) multiple-vortex tornado that paid a deadly visit to Joplin, Missouri, left in its horrific wake 158 fatalities and more than a thousand wounded.

The day after the Joplin tornado a supercell struck the luckless Oklahoma town of El Reno. State medical examiner Eric Pfeifer had begun his first day on the job when the ten casualties were rolled into his office. "Though I'd seen forensic atlases and picture books," he recalls, "until you see firsthand what a tornado can do to the human body, you don't realize how extremely violent they are. The injuries are similar to those that you'd see in a high-speed motor vehicle accident, but they're much more numerous and much more dramatic looking. Bodies can be broken apart to the extent of not being recognizable. People are picked up by the wind and propelled against trees and other objects. Things like trees, nails, glass, and steel are torn loose and can act as a cutting implement. Imagine a piece of sheet metal coming off of a Quonset hut, traveling at 290 miles per hour. It becomes a Waring blender."





On June 24, 2003, proximity to violence made Tim Samaras famous. Funded in part by the first of 17 National Geographic grants that he would receive over the course of his storm-chasing career, Samaras dropped a red, conical, 45-pound





A Calculated Risk

"We're going to get a hit," Tim Samaras says, as his team rushes to place a camera unit in the path of a tornado near Manchester, South Dakota, in 2003. As the funnel passed directly over another probe, instruments recorded a 100-millibar drop in pressure—the largest yet observed inside a twister.

CARSTEN PETER

probe in the direct path of an F4 (4 on the Fujita scale) tornado on the outskirts of Manchester, South Dakota. The probe would record a 100-millibar barometric pressure drop, the most drastic such decrease ever captured at the time. Meanwhile the little town of Manchester was, as Samaras would put it, "literally sucked into the clouds."

After his feat at Manchester, Samaras traveled to Chicago to appear on Oprah Winfrey's TV show. When the host asked him how he had become interested in tornadoes, the storm chaser replied that as a child he'd been mesmerized by the tornado in the opening scenes of *The Wizard of Oz*—that it was, frankly, the only thing about the movie that interested him. Oprah replied, "See, my favorite part is when Glinda the good witch says, 'You've always had the power'"—implying that the storm chaser had missed the most poignant message in the movie.

His mother had given up making him play Little League baseball after she noticed that he would spend game time in the outfield gazing not at the ball but instead at whatever in the sky interested him.

In point of fact, from an early age Samaras had known he had the power to make his dreams come true. From boyhood in Lakewood, Colorado, he had two preoccupations—how things worked and the weather—that would one day converge. His father sold toy trains and airplanes to hobby shops, and worked as a wedding photographer on weekends. The boy held the lighting equipment while his dad took the photos and watched him build model airplanes in the basement. When the elder Samaras saw how much his son enjoyed tinkering, he took out a want ad for used television sets, then piled them all in front of Tim—who promptly took them apart, repaired and reassembled them. Meanwhile his mother had given up making him play Little League baseball after she noticed that he would spend game time in the outfield gazing not at the ball but instead at whatever in the sky interested him.

Samaras became a ham radio operator by the time he was 13 or 14, a radio repair technician at 16, a service-shop foreman at 17. He did not bother to enroll in college. Instead, in 1977 the high school graduate walked into the office of Larry Brown of the University of Denver Research Institute without a résumé. Brown saw something in the teenager and hired him. "Within weeks," Brown says, "it was obvious he could fix things that my most senior technicians couldn't." By 20 Samaras had Pentagon security clearance and was helping to test, build, and

explode weapons systems. "I get paid to blow shit up," he would exult.

A day came during the 1990s—by which time both men had moved over to Applied Research Associates—when Brown took his brilliant protégé into the offices of upper management. There was a problem, Brown informed them: Samaras had begun spending all of his weekends and holidays chasing tornadoes. Likely the company's insurers would come to view him as a liability. He asked Samaras to make his case, which Samaras did: *I never chase storms at night. I never go after a tornado that's rain wrapped. I always err on the side of caution.* Upper management did not wish to test their star engineer's loyalty. They gave him their blessing to continue his new hobby.

The first big storm he pursued was in Limon, Colorado, in 1990. Subsequently he took a storm-spotting class offered by the National Weather Service in the Denver area. It wasn't long before the sight of the five-foot-seven-inch, beak-nosed fellow in the antenna-adorned minivan with STRMCSR vanity plates was ubiquitous across the plains. Samaras had inherited his father's love of photography; he shot cartridge after cartridge of tornado footage and supplied it free of charge to longtime Denver television meteorologist Mike Nelson. The two became fast friends. One day in 1996 Nelson took Samaras to a special screening of the movie *Twister.* The two weather geeks snickered at the liberties Hollywood had taken with the not so glamorous life of storm chasers. "I'm not sure it's gonna make it," Samaras predicted when the movie was over. *Twister* became a blockbuster, and the once obscure demimonde of storm chasers proliferated overnight.

Among Samaras's storm-chaser pals was Roger Hill, who also lived in the Denver area and ran Silver Lining Tours, one of the first in the burgeoning field of tornado-watching tour groups. In February 1998 the two men conceived and hosted the first gathering of what would become the annual Storm Chaser Convention, or ChaserCon, in Samaras's basement. The event grew from about 10 attendees the first year to double that the following year to 50 or 60 the year after that. Like the rest of them, Samaras lived for the marathon chases out across Tornado Alley, followed by all-night drives home through miserable rain. During one chase he left a McDonald's cheeseburger on his dashboard; when a tornado erupted, he declared the cheeseburger to be a token of good fortune, and thereafter he always kept a cheeseburger on the dashboard—sometimes the same one for years. The walls of the Samaras house were festooned with framed photographs of whirling supercells. Each new vehicle became ever more elaborately rigged with radios, antennas, and cameras. A longtime co-worker recalls, "He told me that he would drop his kids off at school, and they'd say, 'Could you let us off a few blocks away?'—because of his crazy car."

The tinkerer began to build probes in his basement. They weren't the first of their kind. But Samaras greatly improved on the existing models by developing a more durable, aerodynamic device that wouldn't fall apart under the withering force of a tornado. After the historic deployment in Manchester, Samaras's genius was duly noted in the record books, and he became first among storm-chasing equals.

Given the new speaking gigs and National Geographic grants, there was nothing else that he could possibly want that he didn't already have. His engineering jobs—first with the Denver Research Institute, then with Applied Research Associates and National Technical Systems, and finally Hyperion Technology Group—accorded him the flexibility to take weeks and even months off. Other scientific organizations made him offers that he routinely turned down. The independence to do his storm research, build his probes, and chase storms was worth more to him than money. Besides, Samaras had become an excellent pitchman when it came to requesting research grants, and he took pride in his ability to stretch a dollar.

One proposal turned his head. In 2009 the Discovery Channel offered him significant money to be one of the lead characters in the reality series *Storm Chasers.* The series became the primary funding source for Samaras's TWISTEX operations—and along the way the Clark Kent-ish engineer became a TV star. Strangers approached him in airports and asked for autographs. Still, the experience was a mixed bag. *Storm Chasers* was TV, not science. "He always told us when we were out there during filming every morning, 'Guys, I don't want you going out there bad-mouthing anybody. Let's keep it professional. We're here to do research, and they'll use it if they want,'" recalls Ed Grubb, who was among the TWISTEX members with cameo roles in *Storm Chasers.*

But the show's producers seemed intent on ratcheting up the drama, and increasingly Samaras wondered if he had made a Faustian bargain. He expressed some relief to his friends when declining ratings caused the show to be canceled in January 2012.

At ChaserCon and on the lecture circuit Samaras seldom passed up the opportunity to inveigh against needless risks. He worried that the growing population of storm chasers would lead to clogged escape routes. But competing with his concern for safety was the considerable pride of a man who had always gone about things his own way. "The thing he told me was that he enjoyed it when people said he couldn't do something," says Grubb. "People said he'd never get probes in front of tornadoes. And numerous times he proved them wrong."

And so the fear that nagged at Tim Samaras was not related to his own welfare. Recalls Geoff Carter of Hyperion Technology Group, "He said it on more than one occasion: 'Somebody's gonna get killed doing this. A chaser, an amateur, a tour group—somebody's gonna get killed.'

"I never expected it would be Tim. He was the other end of the spectrum."

The good news for Samaras during the spring of 2013 was that he'd been liberated from the Discovery Channel and could—as he put it in a tweet—"chase without cameras in our faces." The bad news was that TWISTEX would now have to get by without Discovery's money.

Samaras requested an $80,000 grant from National Geographic to fund not only storm research in the U.S. but also "supertyphoon" investigation overseas. National Geographic awarded him half the sum, the amount in the budget for the U.S. operations, leaving the typhoon project for later consideration. Samaras delivered the news that "we've been partially funded for this year" to his TWISTEX colleagues in an April 7 email: "This means there isn't enough funding for a full-blown TWISTEX program for this year…I wish I had better news for everyone."

The budget-conscious Samaras decided that he would spend the latter part of May on two different projects. The primary focus would be lightning research, funded by the Pentagon and conducted on a wind farm in Concordia, Kansas, among other places, using the truck, a converted former moving van equipped with a titanic high-speed camera that he dubbed the Kahuna, which could capture up to 1.4 million frames per second. Storm chasing would be on the side—with a stripped-down crew on a tight budget, in a single car that did not guzzle gas the way his heavy-duty Ram truck did. That meant driving in one of the small fleet of Cobalts—inexpensive, fuel-efficient cars—that Samaras had purchased for the TWISTEX team back in 2009. Samaras had always envisioned using his truck as the only vehicle in the TWISTEX convoy that would deploy probes at close proximity to a supercell. The Cobalts were to be used only when taking meteorological measurements at a safer distance. But by the conclusion of their mid-May chases, Samaras and his crew had already exhausted half of the National Geographic grant. They decided to switch from the heavy-duty truck to the high-gas-mileage Cobalt.

On May 26 Samaras tweeted, "Off to KS to chase lightning—with tornadoes…gawd I love my job." Accompanying him on the trip were two other members of the TWISTEX team—both of whom were grateful to be along, if for entirely different reasons. Carl Young had met Samaras around 2002 at ChaserCon. Though Samaras had ten years of storm-chasing experience over Young, the latter's brilliance as a meteorologist greatly aided the former's ability to forecast the day's weather events. Young had been devastated by the cancellation of *Storm Chasers;* acting had been his first dream. The photogenic, cleft-chinned Young, whom fellow TWISTEX member Matt Grzych playfully nicknamed Hollywood, was not afraid to challenge Samaras, particularly when evaluating the riskiness of a chase. "Carl was definitely the one to push the envelope," says Grzych, "and Tim would be the one to rein him in, especially for safety reasons. And Tim always had the veto power."

At the beginning of 2013 Young had promised his girlfriend, Dalia Terleckaite, that he was done with chasing. Young's brother, Eric, saw through this. As a boy growing up on the shores of Lake Tahoe, he had watched his older brother become transfixed by the flickers of lightning across the night sky, willing on torrential evenings to spend hours out on a pier on the lake. And so when Eric quizzed his brother over lunch that May about his promise to Terleckaite, Carl dispensed with rationales. "I truly love it," he confessed. At that

moment the younger brother realized that Carl had no intention of quitting.

The same could be said of the other passenger in the Cobalt. Paul Samaras had been born on the same day as his father, 31 years later. When Samaras's two daughters, Amy and Jennifer, were young, he had taken each of them out on a storm chase. Amy became noticeably scared when a fist-size ball of hail cracked the windshield; her first chase would be her last. But young Paul took to the experience immediately. He had inherited the Samaras passion for photography, and it was quickly apparent to everyone else on the TWISTEX team that the shy, scruffy-bearded younger Samaras possessed a creative gift that they lacked. "He just captured things," remembers Tony Laubach. "He made us look like heroes even if we were just taking a piss on the side of the road." Paul sold some of his images at ChaserCon—at bargain-basement rates, since, like his father, he cared deeply about certain things, money not among them.

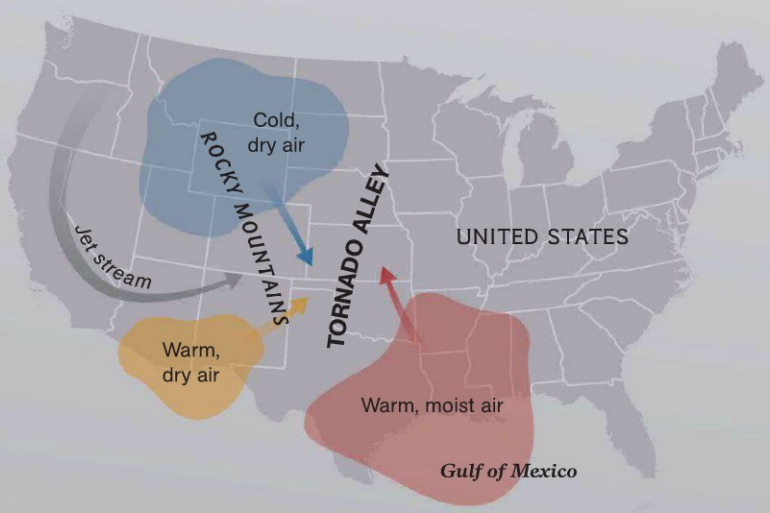
By the late afternoon of Thursday, May 30, fellow TWISTEX co-founders Bruce Lee and Cathy Finley had completed a long day of storm chasing and were driving along Highway 105 a few miles east of Guthrie, Oklahoma, when they saw a white Cobalt parked along the side of the road. Three familiar figures stood nearby, gazing from their elevated post at a new storm firing up to the north near Interstate 35.

"You killed the storm!" one of them moaned as the two researchers joined their colleagues. Lee and Finley acknowledged ruefully that, yes, it did appear that the storm was petering out. That was par for the course, as it had been a somewhat disappointing storm-chasing string for Samaras's crew thus far. They had missed an EF4 tornado near the Oklahoma town of Shawnee, on the 19th—having been, as Samaras reported to National Geographic that evening, "20 minutes too late. Storm chasing can be very frustrating at times." The following day the TWISTEX team misjudged the weather patterns and, like numerous other chasers, followed a storm down to Duncan, Oklahoma—thereby missing the tornado that leveled much of the town of Moore. Another storm-chasing pal who had been at Moore, Lanny Dean, called and gave his account to Samaras, who then proceeded to lecture Dean for having risked venturing into a metropolitan area.

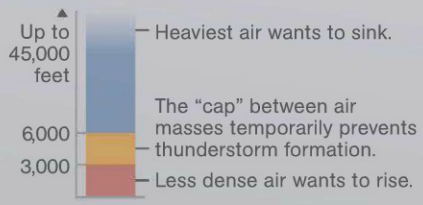
The fear that nagged at Samaras was not related to his own welfare. He said more than once: "Somebody's gonna get killed doing this."

In Harm's Way

Tornadoes have touched down in every state. But big ones happen most regularly each spring in Tornado Alley, from Texas to the northern Great Plains. Here warm, moist air from the Gulf of Mexico collides with fast-moving cold, dry air from the Rockies, generating strong wind shear and atmospheric instability—key elements of tornadic thunderstorms.



Warm, moist air rises until it hits warm, dry air—the cap. If the moist air becomes warmer than the cap, it can punch through it explosively.



HOW A TORNADO FORMS

(1) WIND SHEAR Fast-moving winds roll air below into a horizontal vortex—a spinning tube—above opposing surface winds.

(2) UPDRAFT Warmed by the sun, buoyant air near the ground begins to lift a section of the horizontal vortex into a vertical position.

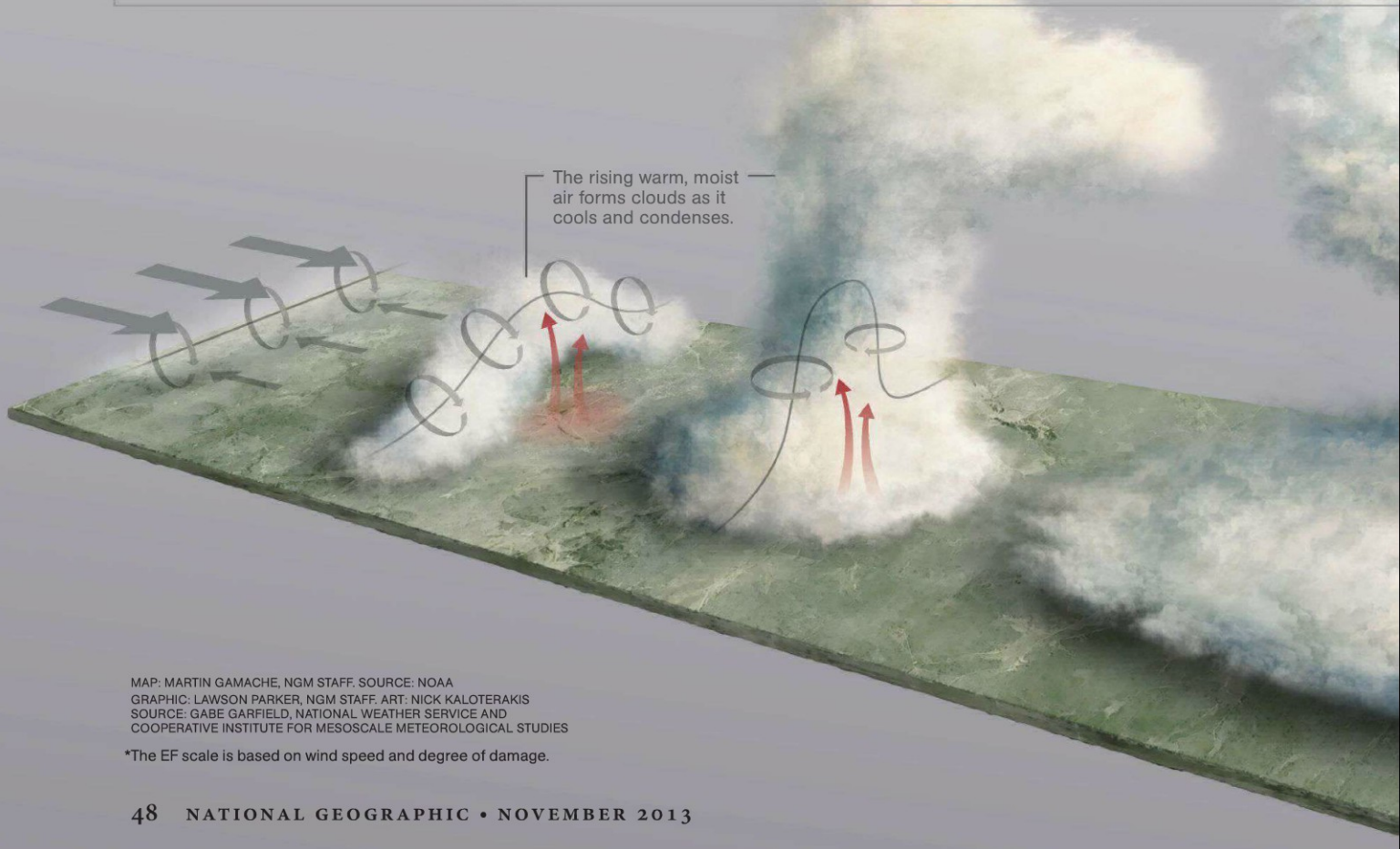
(3) STORM The stronger of two vortices created by the updraft becomes the heart of a thunderstorm. The other one dies.

EL RENO TIME LINE, May 31, 2013

Forecasters note extreme atmospheric instability in Oklahoma.

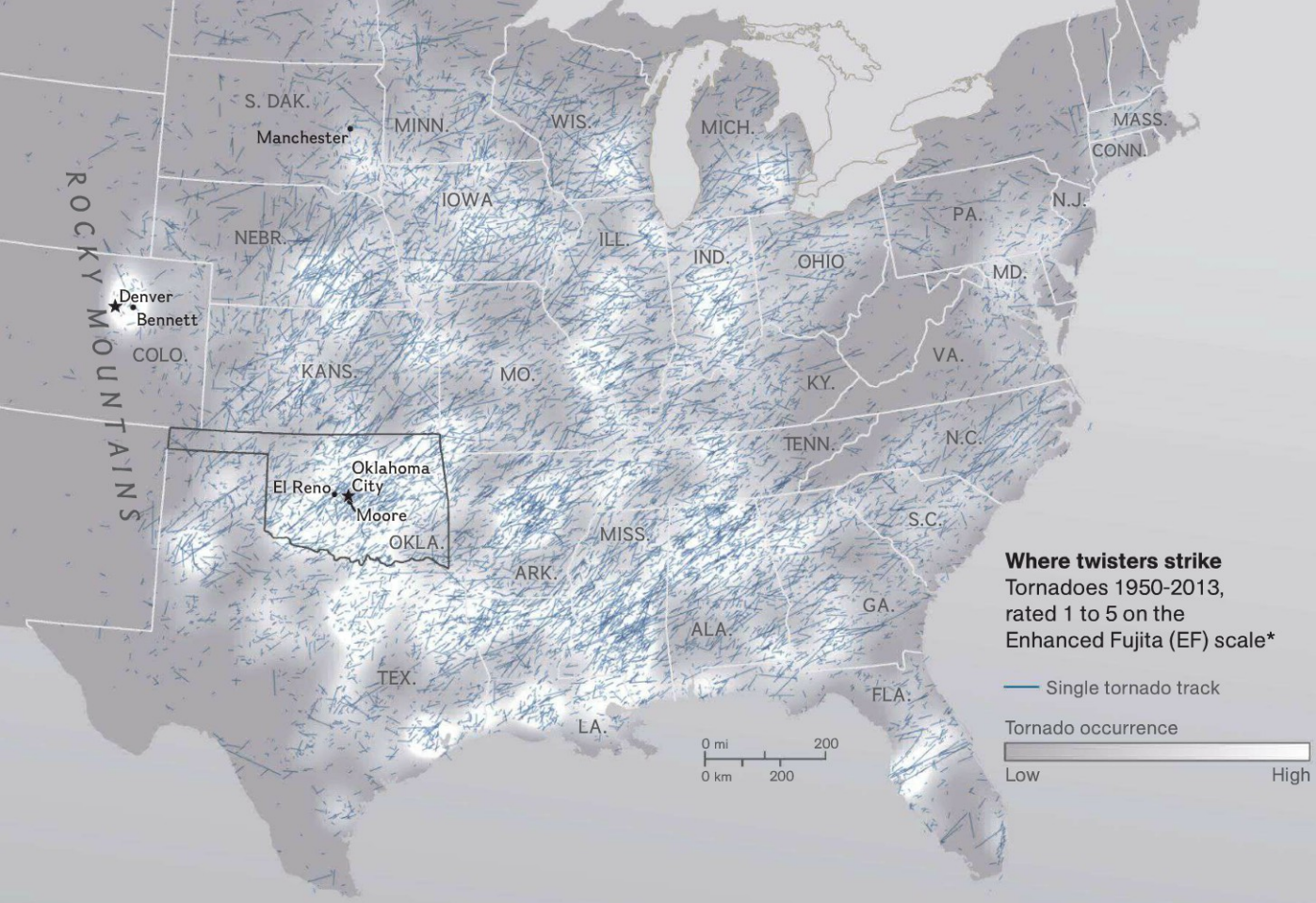
The National Weather Service issues a tornado watch for El Reno at 3:30 p.m.

The El Reno thunderstorm forms in under an hour, faster than most.



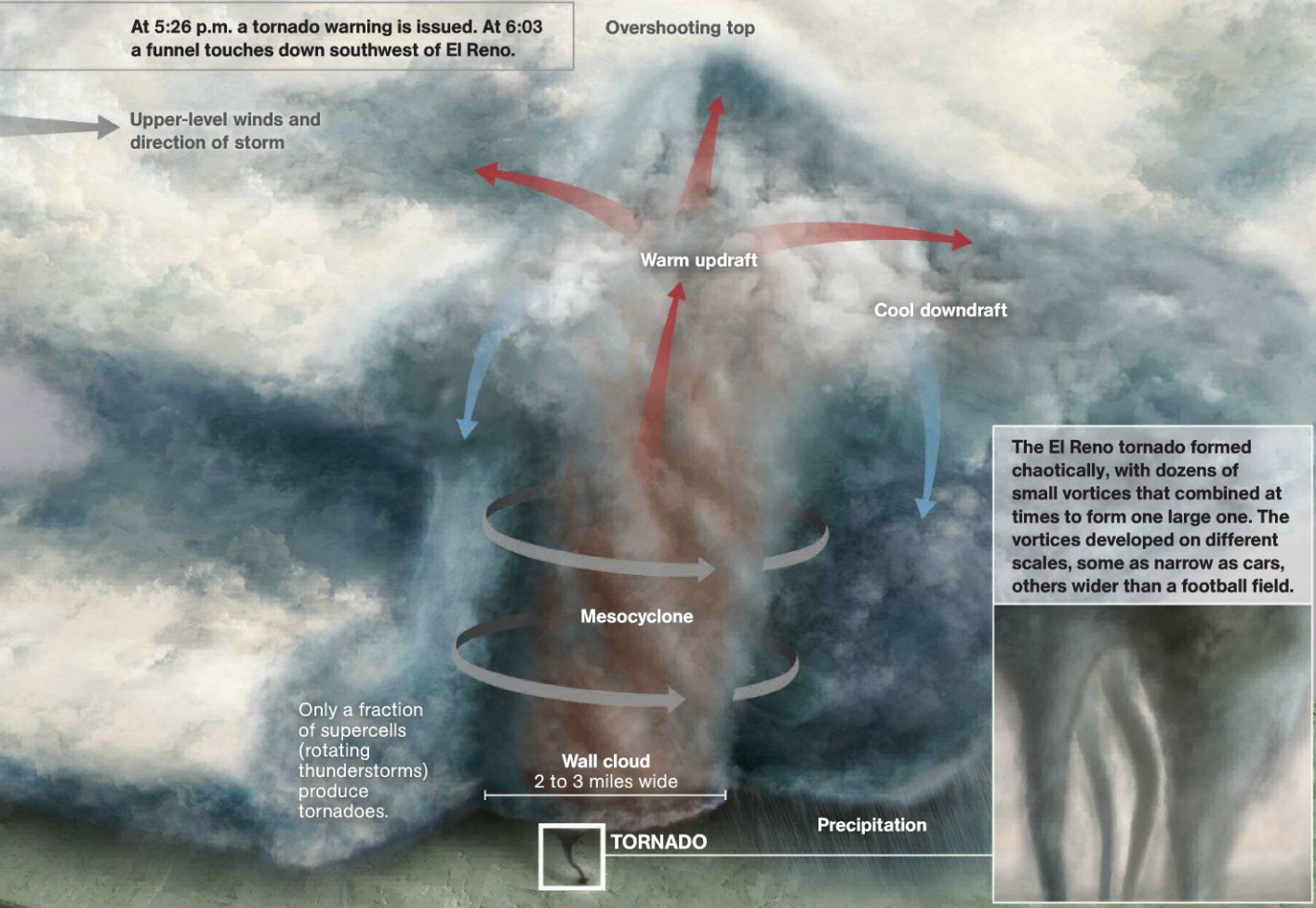
MAP: MARTIN GAMACHE, NGM STAFF. SOURCE: NOAA
GRAPHIC: LAWSON PARKER, NGM STAFF. ART: NICK KALOTERAKIS
SOURCE: GABE GARFIELD, NATIONAL WEATHER SERVICE AND COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES

*The EF scale is based on wind speed and degree of damage.



④ SUPERCELL Upper-level winds tilt the rotating updraft, called a mesocyclone. This allows the storm to keep growing, as warm air is sucked into the storm away from the cool downdraft.

At 5:26 p.m. a tornado warning is issued. At 6:03 a funnel touches down southwest of El Reno.



The El Reno tornado formed chaotically, with dozens of small vortices that combined at times to form one large one. The vortices developed on different scales, some as narrow as cars, others wider than a football field.

The tornado revealed its deadly intentions, mauling wherever it went. Brick homes were pulverized. A big and sturdy dairy barn disappeared entirely.

"Lanny, you know better!" Samaras said. But then he began cursing himself: "Damn it, I missed it!" In more than two decades of storm chasing Samaras had witnessed only a single F4 tornado—in Hallam, Nebraska, on May 22, 2004. He had yet to lay eyes on an EF5 like the one in Moore.

That day, May 30, at sunset over the Oklahoma highway, it was already evident that the following day would bring weather that only a storm chaser could love. The forecast called for hot and humid conditions, which would build up tremendous energy in the atmosphere. There would be enough wind shear to make a thunderstorm spin. Somewhere in this state, perhaps close to Oklahoma City, Mother Nature would, in all likelihood, put on a glorious horror show.

Lee and Finley told the others that they didn't intend to stick around. There were way too many storm chasers already in the vicinity—hundreds of them. Doing safe and honest research while navigating through the gawkers sounded like a nightmare to them. For his part, Samaras didn't let on what his crew's plans would be. The lightning truck was parked near the courthouse steps in Alva, Oklahoma, two hours north of where they now stood. Their motel in Concordia, Kansas, lay another four hours to the north. The TWISTEX team had two more evenings' worth of lightning research ahead of them. But in the meantime Samaras had been discussing with Lanny Dean a possible deployment of devices they had been developing that measured a tornado's low-frequency sound waves. It happened that Dean was also a tornado tour-group operator, and on the 31st his bus was fully booked. If the two storm chasers were to deploy their experimental devices that day, it would fall to Samaras and his team to do so.

If. The plans were not firm. Still, the man who four days ago had tweeted, "gawd I love my job," was disinclined to miss out on what tomorrow's weather might bring.

"See you in June," Young said to Lee and Finley, as they departed.

> Storms now initiating south of Watonga along triple point. Dangerous day ahead for OK—stay weather savvy!
> *—final tweet from Tim Samaras, May 31, 2013*

From beginning to end, the storm was a thing both magisterial and brutish. Conditions had

been ripe for a supercell all day—held back by a high cap of warmer air that, once finally punctured by the surface air, guaranteed a furious updraft. By 1:30 in the afternoon, with the skies a moist blue, the meteorologists at Channel 9 in Oklahoma City were already forecasting that heavy chunks of hail would pummel the region 20 miles west of the metropolitan area and that one or more tornadoes might well rumble into the city. The convective available potential energy had risen to an alarming 4,000 joules per kilogram. North of El Reno a dark anvil materialized over the town of Kingfisher. A heavy rain shaft off to the west drenched Greenfield; farther westward a separate storm fell on Weatherford. All signs pointed to the storm organizing itself into a supercell and pushing east toward El Reno. Meanwhile a large gaggle of storm chasers huddled together and compared notes at the Conoco station in El Reno, seeking to discern the storm's path and thus their own.

By five the number of storms had dwindled to three, stretching diagonally from Hennessey at the northeast to Hinton at the southwest—a 25-mile-an-hour battering ram whose midsection was destined for El Reno. By 5:30 a large wall cloud developed under a supercell updraft and hovered spinning and low to the ground six miles west of town. Other wall clouds formed to the north, at times obscured by thick curtains of rain. West of Kingfisher the first tornado dropped, multiple vortices whirling. A second funnel appeared near Geary.

Southwest of El Reno something else was happening. But for several long minutes an impenetrable rain wrap obscured the form of the storm. Then, at about five minutes before six, the curtain lifted slightly, and a bloblike structure appeared, dangling like a wispy rope over the eerily illuminated pea green farmland. It sat there, not quite yet declaring itself—a warped and blurry sword of Damocles twirling wickedly over a trembling countryside.

At just before 6:04 p.m. the sword fell. An ebony wedge slammed down onto the pavement of Reuter Road and the wheat fields on either side of it, three miles south of Interstate 40. Multiple vortices slithered out. As the tornado materialized to the south, more moisture flowed into it. The tornado remained shaggy and semicoherent. It seemed, in its sluggish and muddled state, unsure of what to do next.

Then it revealed its deadly intentions, mauling wherever it went. Brick homes were pulverized. A big and sturdy dairy barn disappeared entirely. Near the intersection of 15th and South Airport a local deputy stood outside for a bit and watched the storm approach. When his ears popped from the sudden loss of pressure, he hastily ushered his family into a neighbor's cellar, where they sat for several minutes listening to the howling winds overhead tear their home to ribbons.

The monster's appetite was at once growing and oddly fickle. In the 40 or so minutes it had left to live, it slapped bales of hay into a wheat field, disassembled machinery and scattered the parts for miles around, tossed a truck into a pond, lopped off the entire second floor of a home. And during its waning moments on Earth, after savaging an RV park on the south side of Interstate 40, the tornado crossed the freeway, barreled into the OKC West Livestock Market, apparently hoisted seven cattle and a 32-foot stock trailer into the air, and deposited all of them in a pasture a half mile south of I-40—the trailer reduced to rubble, the cows alive with nary a scratch on them.

But 25 minutes before that improbable feat the storm had spewed baseball-size hail at the town of El Reno as its funnel spun southeast toward the regional airport. Just to the north, three pairs of eyes watched its progress from a little white car as the tornado crossed South Chiles Road, traveling eastward at a speed exceeding 20 miles an hour. It was 6:12 p.m.

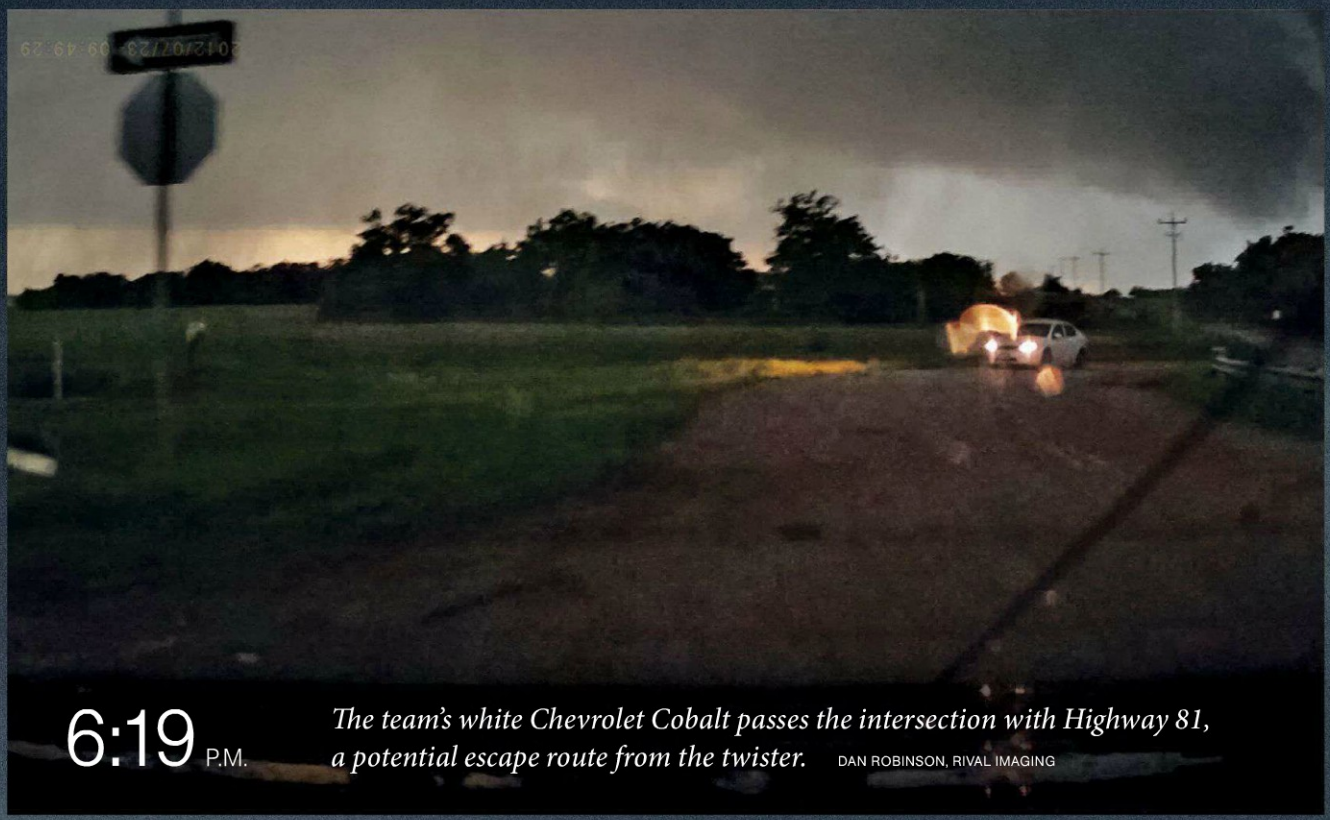
Roll the tape.

"Barely missed that airport," observes the driver, Carl Young, as the car pushes north toward Reuter Road.

Tim Samaras answers his phone. It sounds like a member of the media. "Yeah, yeah, the tornado's about 500 yards away—I really can't talk right now," he says. "It's just south of El Reno… It's gonna be on the ground for a long time, and it's heading right for Oklahoma City."

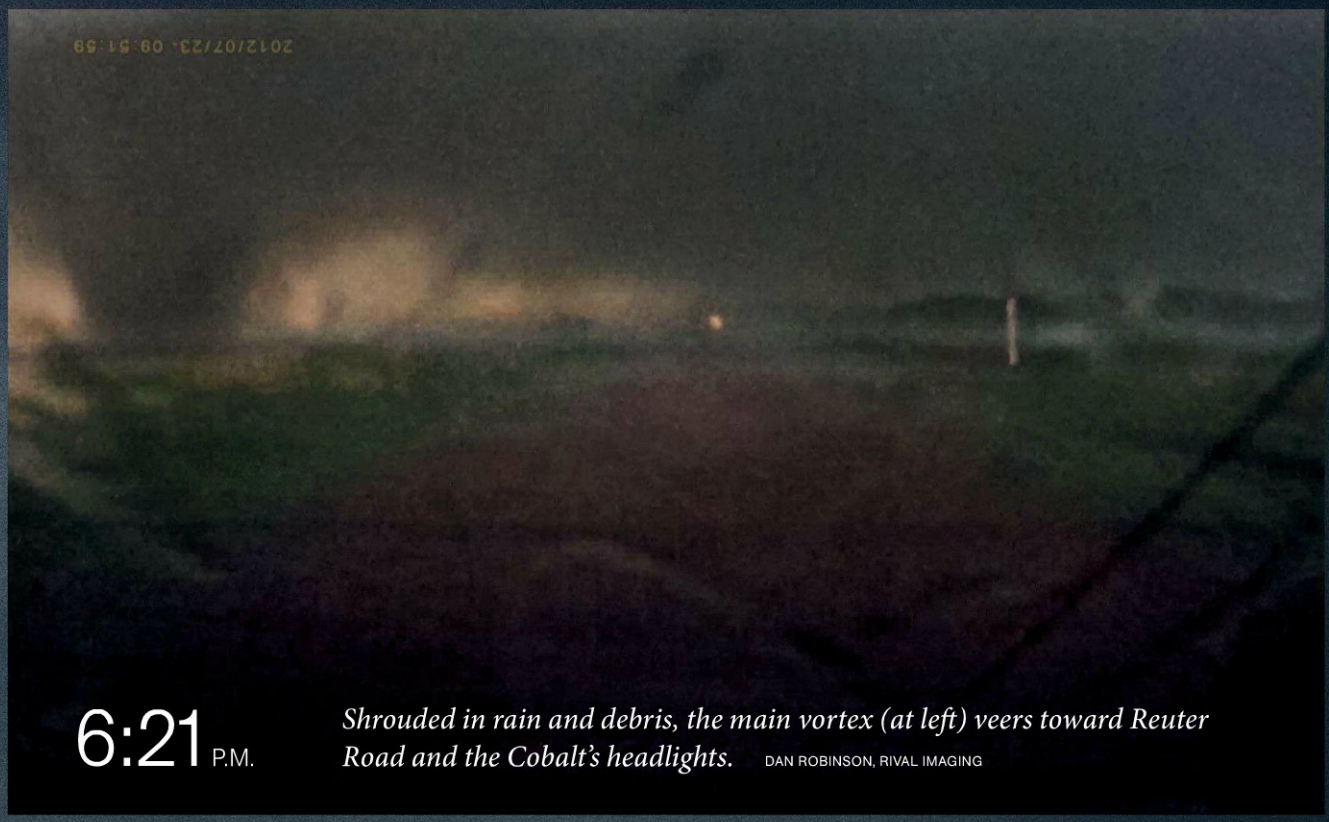
Samaras hangs up. The tornado to the south has soaked up so much moisture that it has become shrouded in precipitation. "It's pretty well rain wrapped," Young says as he squints through the smudged windshield. "In fact, it's hard to tell what the hell it's doing now."

"OK, stop sign up here," *(Continued on page 58)*



6:19 P.M.

The team's white Chevrolet Cobalt passes the intersection with Highway 81, a potential escape route from the twister. DAN ROBINSON, RIVAL IMAGING



6:21 P.M.

Shrouded in rain and debris, the main vortex (at left) veers toward Reuter Road and the Cobalt's headlights. DAN ROBINSON, RIVAL IMAGING

6:23 P.M., MAY 31, 2013

Nearing its maximum width of 2.6 miles, the tornado overtakes the team's Cobalt. Hidden inside the swirling mass are violent subvortices; one strikes the car, hurling it into a field.

GENE E. MOORE

Collision Course

On May 31 Tim Samaras and team drove into the path of a powerful, erratic storm near El Reno, Oklahoma. It rapidly doubled in size.



THE TORNADO

6:03:49 P.M.

The twister is unusually wide from the second it touches down—a half mile across. Multiple vortices appear and disappear, confusing chasers as the tornado moves south-southeast.

6:09

Rain wraps around the tornado, hiding it. Accelerating to 40 to 50 miles an hour, the storm turns east, forming subvortices around the main funnel; some last only seconds.

6:15

Just missing El Reno's airport, the tornado pauses, possibly looping in its track, then reorganizes into a single large vortex that rapidly expands and surges eastward.

TIM SAMARAS

6:04:30 P.M.

From the shoulder of a farm road southwest of El Reno, Tim Samaras and his TWISTEX team watch the tornado forming. "This is gonna be a monster wedge," he says.

6:12

Racing to catch up with the fast-moving twister, the team navigates around the airport. But rain obscures their view. "Turn to the north," Samaras tells Carl Young.

6:16

Once on Reuter Road, the team races east, looking for a chance to deploy instrument probes. But they have trouble getting ahead of the tornado on the slippery road.

*The parent storm was responsible for 22 deaths; 8 are shown on this map.

**Generalized tornado track: From start to 6:18 p.m. and 6:26 to end, data collected by the Advanced Radar Research Center of the University of Oklahoma's RaXpol instrument. From 6:18 to 6:26, data provided by the Center for Severe Weather Research's Doppler on Wheels.

6:19

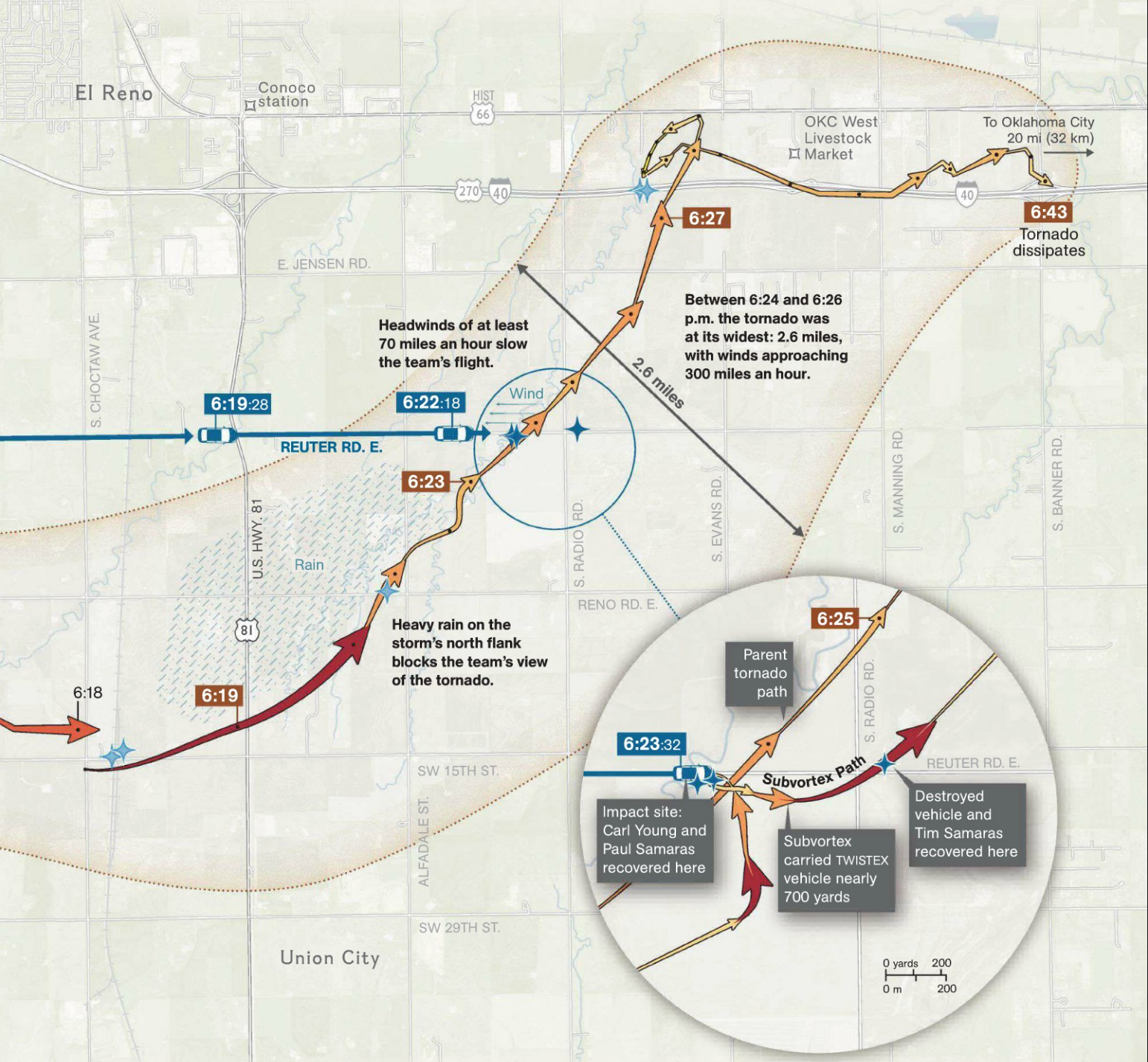
As it crosses Highway 81, the twister veers to the northeast, still expanding. Surface winds feeding the storm uproot trees well beyond the base of the funnel.

6:23

The rain parts, revealing the main vortex. A few minutes later, wind speeds approach 300 miles an hour as the tornado's diameter maxes out.

6:27

Steered by the rotating parent storm, the twister makes a loop north of I-40 and heads east. Having spent 40 minutes on the ground, it finally dissipates at 6:43 p.m.



6:19:28

The team pauses briefly at the Highway 81 intersection, empty of traffic because of closures. The tornado suddenly speeds up. "What a beast," Young says.

6:22:18

Aware of their perilous situation, Samaras urges Young to keep moving. A driver just ahead of them on the road is the last to see them before they disappear in the storm.

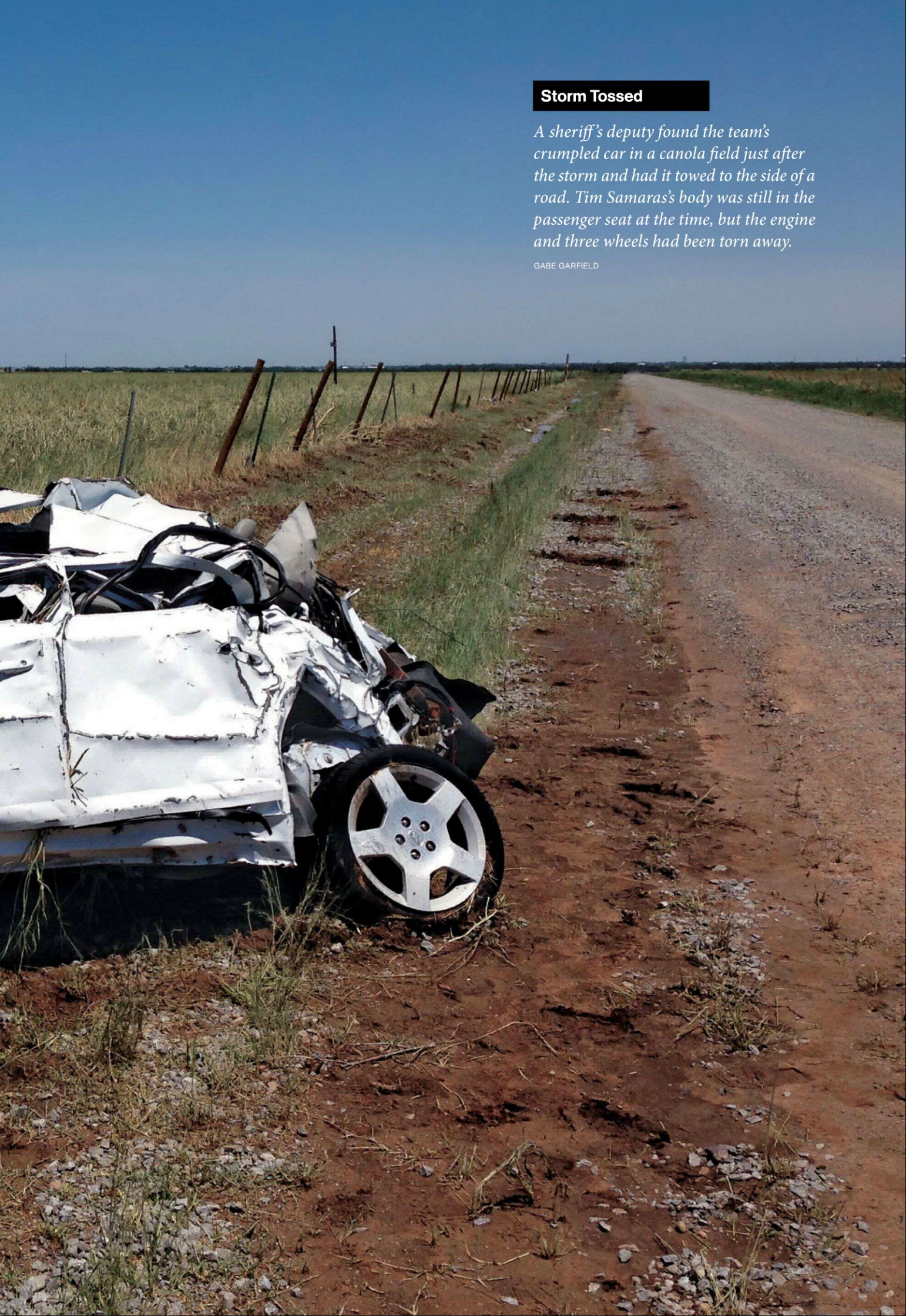
6:23:32

As radar imagery later shows, one of several violent subvortices swings around the main vortex and collides with the team's car, flinging it east into a field just past Radio Road.

MARTIN GAMACHE, NGM STAFF

SOURCES: ERIK FOX; GABE GARFIELD, NATIONAL WEATHER SERVICE AND COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES; TIM MARSHALL, HAAG GLOBAL; DAN ROBINSON, STORM HIGHWAY; JOSHUA WURMAN, CENTER FOR SEVERE WEATHER RESEARCH





Storm Tossed

A sheriff's deputy found the team's crumpled car in a canola field just after the storm and had it towed to the side of a road. Tim Samaras's body was still in the passenger seat at the time, but the engine and three wheels had been torn away.

GABE GARFIELD

Samaras says loudly as Highway 81 comes into view. "If there's any chance to deploy, we've gotta go east and drive south, and deploy our instruments when the tornado's due west. That's our only chance."

As they slow down near the intersection, the black wedge fills their line of vision to the south. "Wow," murmurs Young. "What a beast."

But no one in the car can tell how big the beast beneath the dark rain cloud really is. They can't see the tornado, which is uprooting telephone poles, slamming one of them into a pickup truck that contains two amateur storm chasers—and then hoisting the truck and its passengers into the air, flinging them 300 yards, sucking off their boots before hurling them lifeless to the ground. They can't see the tornado sling hail clear through the windows of a second car and strip it clean of its engine while rolling the vehicle for 15 to 20 seconds. They see only the dark, blurry implication of violence.



After the Storm

Tim Samaras's laptop computer was recovered from a creek (right). A search for items was conducted in the days following his death. A makeshift memorial (far right) on Reuter Road honors the three chasers and TWISTEX*, the research group Tim Samaras led.*

RICHARD BARNES (BOTH)

Highway 81 is uncluttered. In fact, it's closed to southbound traffic. Northbound lies their immediate escape route. By now virtually all the other storm chasers have elected to flee El Reno's environs. Samaras and his team could do the same. They've done the same many times in the past. But there are other factors to consider. The road is drivable. The tornado is epic.

They are near its path. It's understood: The TWISTEX team will deploy their probes.

"There you go," says Samaras approvingly as Young eases the Cobalt across the highway and continues along the gravelly road. Anticipating rough road conditions, Young has laid his camera on the floorboard. But he says with measured optimism, "All right, so this is dry out here. Hasn't been impacted by any rain."

"This thing is moving 30 to 40 miles an hour to the east," Samaras mutters. He's clearly puzzled. The sky to the south is a swirling gray cauldron. The wedge and the rain wrapping have effectively blocked the tornado from view. "Ah, I see it," he declares. Then, annoyed: "Arrgh. Maybe I don't. Sorry—just a bunch of rain here."

What he sees, when he does at last see it, is something that Tim Samaras has never seen before and will never see again. It is the sight that has sent experienced storm chasers at safer distances scurrying. The tornado suddenly bends its path to the left—the sign, ordinarily, of a dissipating vortex, except in this case the tornado grows.

In the span of a minute it swells grotesquely, from less than a mile in diameter to two and a half times that size—larger than any other on record. Around the mother tornado—which has suddenly begun to move at 40 to 50 miles an hour, with internal wind speeds four times that—four or five subvortices whirl up and down with wind speeds approaching 300 miles an hour. The storm turns hard and with unrelenting velocity charges north up Alfadale Road, chewing up everything in its path, bound for Reuter Road, the street where it first touched down.

As the Cobalt approaches the intersection of Reuter and Alfadale, Tim Samaras stares out the passenger window toward the south. When he sees what he sees, his voice is both calm and urgent. "In fact, uh, keep going," he says. "This is a very bad spot."





The tape clicks off at 6:20 p.m., three minutes before the storm and its chasers meet.

Less than an hour later, at 7:06 that Friday evening, a sergeant with the Canadian County sheriff's office who had just paid a visit to his newly destroyed farm was cruising along Reuter Road when he saw a crushed vehicle sitting in a canola field north of the road. But because the sky was still spewing rain and hail, the field was too mushy for him to cross. He came back later that evening and made it to the driver's side of the car. There was no one in that seat. Then he saw the passenger. The sergeant got on his radio and advised that a corpse would need

to be cut out of a wrecked vehicle.

A lieutenant arrived on the scene and happened to notice a body in a ditch a quarter mile to the west of the vehicle, lying facedown in a creek. Concerned that flooding would wash the body away, the lieutenant and the sergeant pulled it out of the water and carried it over to the roadside near the car. In the pocket of the corpse was a wallet with identification for a Carl Young of South Lake Tahoe, California. The VIN of the white car came back as belonging to Tim Samaras—which matched the driver's license found in the pocket of the passenger.

A mile south of the mangled white car, Union City firemen had found another crumpled vehicle and nearby, floating down a creek, a 35-year-old oil field worker and amateur storm chaser named Richard Henderson. Two other men were found dead in separate vehicles a mile west of where Henderson had been killed. And on Interstate 40 the tornado had sucked a mother and her infant out of a sports utility vehicle, whereupon they were found battered to death amid a field of debris. All in all, the storm killed 22 people, including a family of six Guatemalans who had taken shelter in a drainage ditch, only to be swallowed up by floodwaters and carried several miles downstream to the Deep Fork River.

For others in the storm-chasing community, one question was most excruciating: If it had happened to Tim Samaras, couldn't it also happen to them?

At dawn the weary lieutenant decided to take a look one last time along Reuter Road. As the sky lightened, he discovered another body, also facedown in the creek, 15 feet from where the first strewn corpse had been found. He called the medical examiner's office and waited for the car to arrive.

The medical examiner, Eric Pfeifer, received descriptions by phone from those believed to be the families of the deceased found along Reuter Road. The hook nose of the corpse in the passenger seat matched that of Tim Samaras. The cleft chin, that of Carl Young. The black, scruffy beard, that of Paul Samaras.

Kathy Samaras and her daughter Amy flew down to Oklahoma City three days after the tornado. They wanted to visit the scene of the accident. It surprised them to see, laid on the ground at the edge of Reuter Road where the Cobalt and Tim had been found, three long-stemmed roses. It also surprised them that the Oklahoma City mortuary director, who had done his level best to make Tim presentable for viewing, refused to be paid for his efforts.

"He was doing research, trying to save lives in our community," the director said firmly, and that was the end of the matter.

Other matters are not so cut-and-dried. Despite three additional videotapes that have surfaced since the tragedy at El Reno—one by a storm chaser whose car was about a quarter mile from the Cobalt when it disappeared from view, another by a storm chaser whose footage appears to show a small vehicle falling out of the sky, and a third that was recovered from Paul Samaras's camera—no one will ever know for sure what happened at 6:23 p.m. on May 31, 2013. Was the TWISTEX team able to see the tornado before it hit them? Were they attempting to deploy their probes at the time, or to outrace the tornado, or to stay put? Had the Cobalt been sucked up by one of the ferociously spinning vortices? For others in the storm-chasing community, one question was most excruciating: If it had happened to Tim Samaras, couldn't it also happen to them? Every one of them knew the answer. Yet not a single one of them vowed to give up the chase. Nor, in truth, would have Tim Samaras.

During the funeral of father and son Samaras, the pastor placed a McDonald's cheeseburger near the podium, where storm chaser after storm chaser paid tribute. Among the others who said a few words were Kathy Samaras, daughters Amy and Jennifer—and, standing alongside them, holding their hands, a 35-year-old man whom few in the audience knew.

His name was Matt Winter, and he was Tim Samaras's other son, though he himself had learned this fact only seven years earlier. Growing up in Des Moines, the boy had maintained an odd fascination for severe weather that his parents had not nurtured. On his 11th birthday a tornado had blown through west of town; while everyone else at his birthday party had clambered into the basement, Winter pleaded to be allowed to stand outside and watch. At the age of 26 he followed National Geographic's online coverage of Tim Samaras dropping his probes in the path of the Manchester, South Dakota, tornado. Three years later, in 2006, at a Doppler weather conference in Des Moines, he heard Samaras speak. It was after this event that Winter's mother figured she should sit her son down and tell him about the man she used to date in Lakewood, Colorado, before either of them was married.

After that conversation, the woman called Samaras, to whom she hadn't spoken since learning she was pregnant nearly 30 years earlier. He requested that she purchase a DNA kit. When the results came back as a 99.9 percent match, Samaras sent an email to Matt: "I want you to know that I'm very happy and proud to find out that you're my son." The Samaras family welcomed Matt into their home. Thereafter the two men got together whenever they could. Samaras sent Matt photographs of lightning and tornadoes. As a birthday present, the son received the father's book, *Tornado Hunter.* The inscription inside read: "This gives you an insight into who I am, and why I do what I do. Love, Dad."

Like the surviving Samarases, Winter spoke for a few minutes as they stood together before the 800 gathered that somber day in early June. He did not, however, share his most poignant story. Just the previous September, Samaras had gone to visit Winter in Des Moines. They were eating dinner at an Applebee's, chatting about the weather and science as they tended to do, when Winter decided to ask Samaras point-blank, "If something ever happened to you out in the field, how do you think Kathy would handle it?"

Samaras did not seem startled by the question. "Matt," he replied, "Kathy's a strong woman. She understands this is my passion. And if something happened to me, she'd move on."

On the drive back to his hotel, Samaras returned to the subject unprompted. "If something did happen to me or my team out in the field," he said, "I'm going to go down getting my data. That's the only reason I chase. It's for the data."

But then, Samaras added a new thought—a flash of elemental romance within the man's stoic scientific core. "And it better not be a little rope tornado that does it. It better be a multivortex or a wedge," he said. "I don't want to be taken by a skinny little rope."

Regaining the engineer's stolid composure, he concluded, "And if it happens, I'm going to go out collecting my data."

The storm chaser left his son with that forecast—a perfect one, as it turned out—and thereafter drove off, to an eternity of awaiting roads and severely great weather. □

With additional reporting by Samantha Larson.

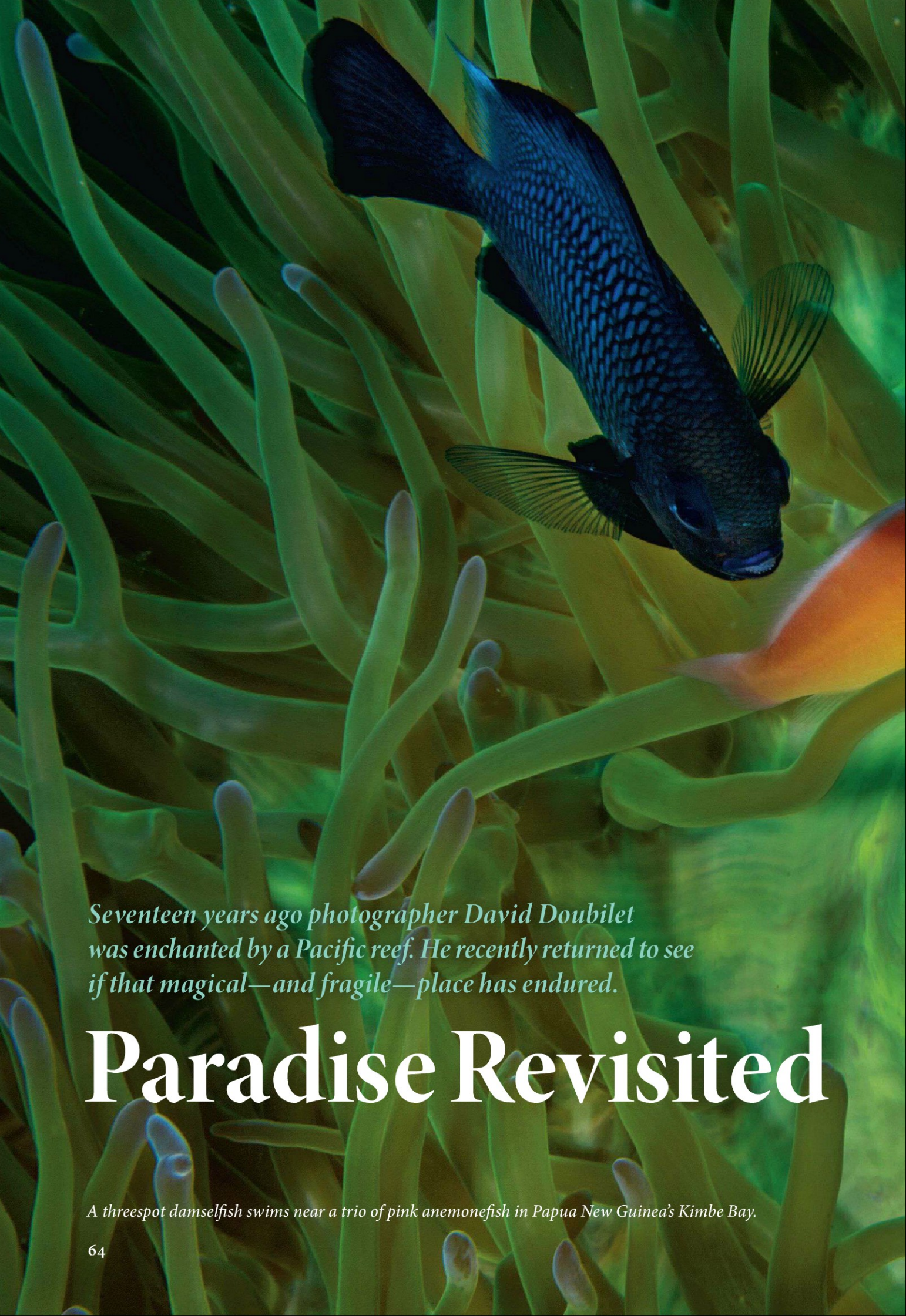




Awesome Force

Even as the sky turns black and the wind bends the wheat, Tim Samaras finds a moment during the 2012 Kingfisher storm to contemplate the power of the atmosphere.

CARSTEN PETER



Seventeen years ago photographer David Doubilet was enchanted by a Pacific reef. He recently returned to see if that magical—and fragile—place has endured.

Paradise Revisited

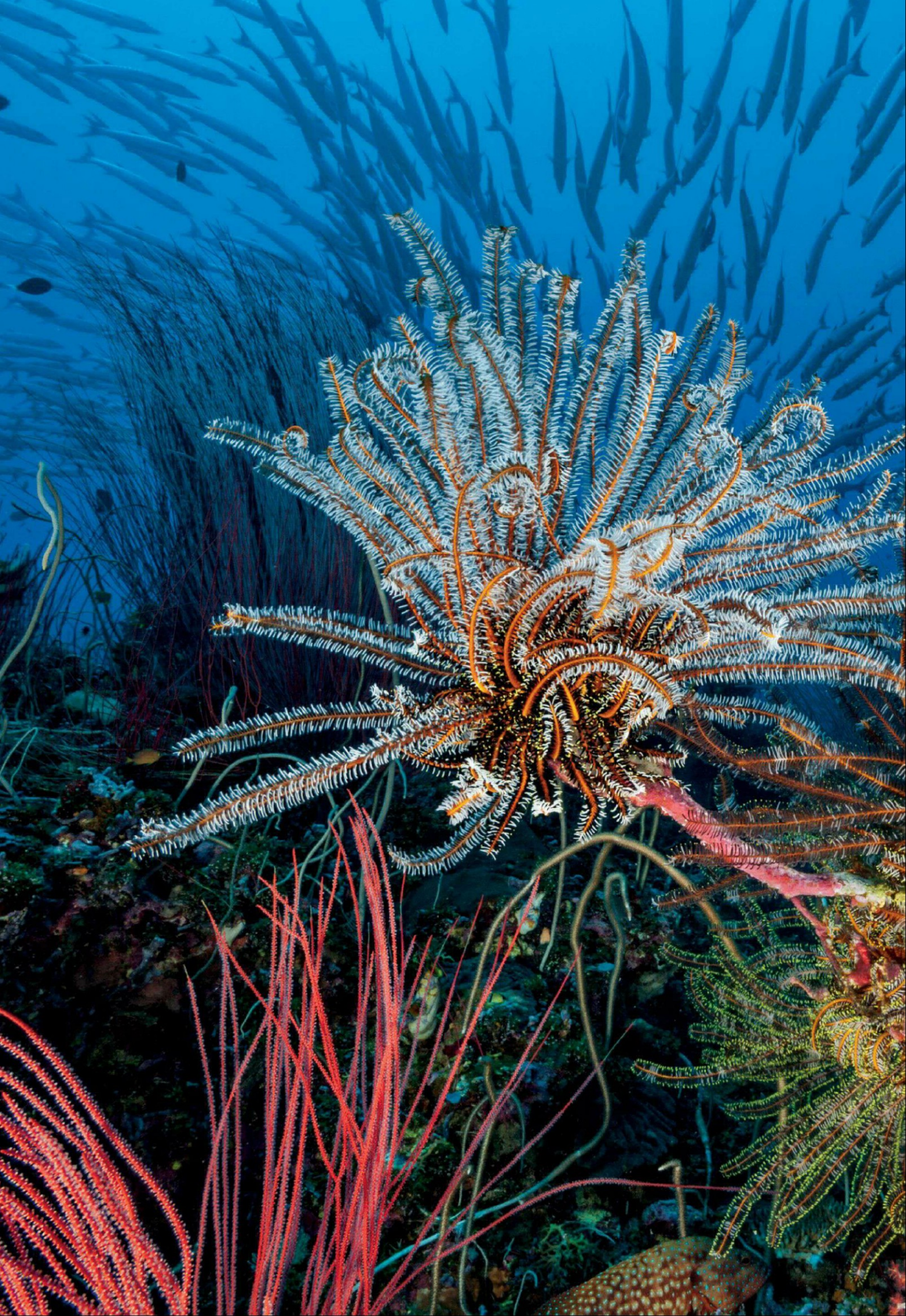
A threespot damselfish swims near a trio of pink anemonefish in Papua New Guinea's Kimbe Bay.







Its flippers spread like wings, a hawksbill sea turtle flies past batfish and barracuda. Submerged peaks attract many species from the open ocean and make Kimbe Bay a haven of biodiversity.





Animals that look like plants, feather star crinoids sweep plankton from Kimbe's waters. With 900 species of reef fish, the bay literally pulses with life—a movable feast for predators like these barracuda.



By Cathy Newman Photographs by David Doubilet

THERE IS A KINGDOM of coral in the principality of the Pacific Ocean called Kimbe Bay. "It is a world," says photographer David Doubilet, "more alien than the edges of space." Unlike cold space, it lives and breathes, and in its universe are galaxies of fish and coral formations as spectacular as the burst of a supernova. The bay, shaped like the cup of a chalice, sits on the coast of New Britain, Papua New Guinea. An uneasy geology—the region straddles two colliding plates—has produced a landscape of volcanoes (three of them active); a narrow coastal shelf that falls off, as if at the end of the world, into an abyss a mile and a quarter deep; and underwater mountains crowned, over the course of millennia, by reefs.

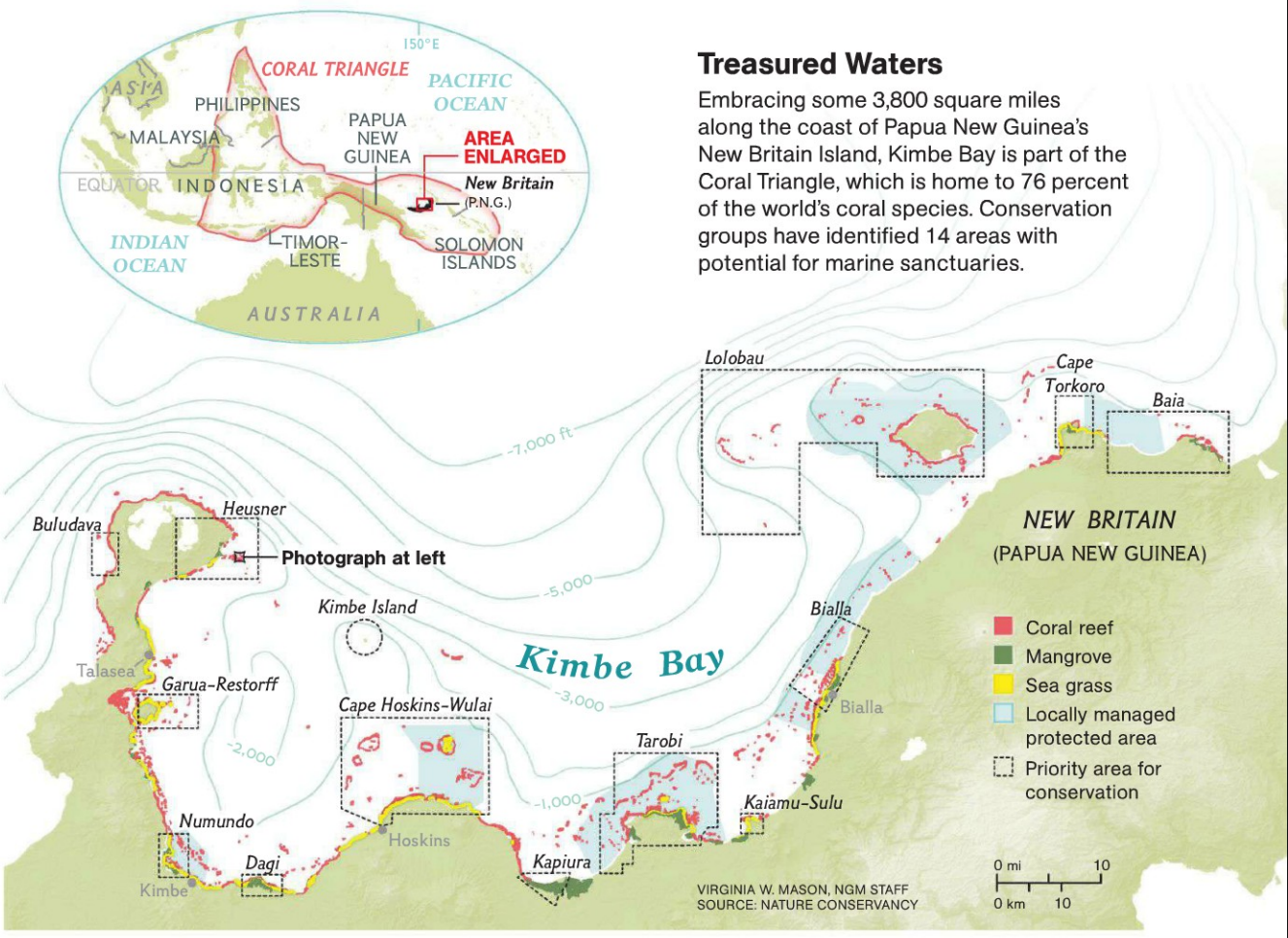
Seventeen years ago Doubilet spent eight days at Kimbe for a story, and the experience—though to call it an enchantment would be closer to fact—provoked a longing to return. It was an obsession born of a memory of a submerged paradise with silver schools of fish, meadows of red sea whips, and water with the clarity of crystal. Was paradise intact? he wondered.

"Some reefs," he says, "are kinetic, like an abstract by Jackson Pollock." Kimbe—Doubilet's memory reef—is languid, "like an Impressionist painting, a Monet." To tally the marine life that sways, swims, or crawls in those currents is to witness diversity in bloom. The accounting includes 536 types of coral (more than half the world's species) and about 900 species of reef fish. Marvels small (the pygmy seahorse, so tiny it can fit on a pinkie fingernail) and large (the sperm whale) share its waters.

A list is one thing. To explain this diversity is another. There is no simple explanation. It is a congruence of geography, ocean currents, temperature, and the vagaries of evolution.

What can be said simply is that the reef remains as vibrant today as it was 17 years ago, unlike so many others in the world, because it is so remote. It does not contend with the population pressure of, say, reefs off Asia. There is no





commercial fishing. It also thrives because it is so well cared for. Among its advocates are the Nature Conservancy, which has designed a plan for 14 marine protected areas in the bay, with support from a locally based conservation and education organization called Mahonia Na Dari (Guardian of the Sea in native parlance), along with the Papua New Guinea Centre for Locally Managed Areas, which helps communities manage and protect their resources.

If one wants to see what a healthy reef looks like, Kimbe is it, says Geoffrey Jones, professor of marine biology at James Cook University in Townsville, Australia, who has studied it for 16 years. Its uniqueness includes an unusual abundance of gobies, small fish that are extreme habitat specialists. Some spend their entire lives in a single type of coral in a single location. "Should that particular coral disappear," he says, "the fish would vanish too."

For now, fish and coral are there. Note the qualifier, "for now." Reefs, it must be said again and again, are perishable. They are vulnerable to ocean acidification, overfishing, runoff from agriculture, and most of all, global warming, which provokes a biological chain of events that ends in coral bleaching to a skeletal white.

Memory beguiles us; we hope all will be as perfect as imagined. Reality intrudes. "We arrived during one of the worst monsoons in several decades," Doubilet said of his return. Climate change disrupts weather patterns across the globe; at Kimbe Bay the monsoon season intruded into a month that is habitually clear and crisp. Torrential rain brought runoff that clouded the inner waters, forcing him to focus on reefs farther from shore.

Even so, Kimbe Bay endures. The silver fish, the brilliant coral, the crimson sea whips that haunted Doubilet 17 years ago are still there. *For now.* More than half of Papua New Guinea's reefs are threatened. Reefs are fragile—as fragile and haunting as remembered dreams. □

Cathy Newman is an editor at large. David Doubilet saw his first coral reef, in the Bahamas, at age 12.



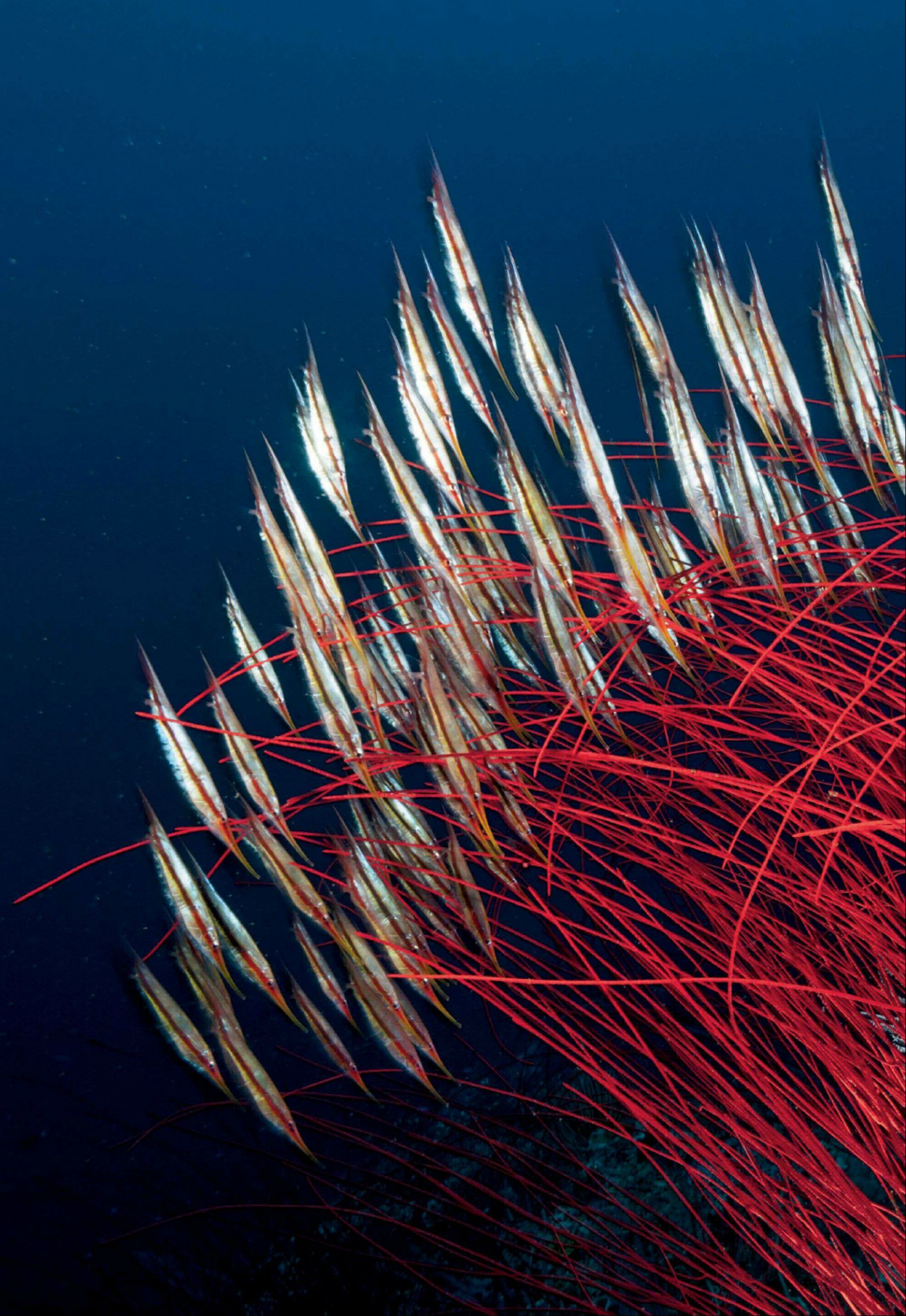


A garden of delicate coral is sheltered from storms in the lee of a nearby peninsula. Kimbe's reefs help sustain local fishermen, some of whom still rely on traditional outrigger canoes.



A 60-foot-tall tower of barracuda rises past photographer Doubilet's wife and collaborator, marine biologist Jennifer Hayes. Many of Kimbe's coral pinnacles host a resident school of barracuda—a sign of a robust reef.







Sharp bellied and nearly flat, razorfish swim in perfect formation as they rush for cover among the branches of a red sea whip. Says Doubilet: "It's gratifying to see that wonders still abound in Kimbe Bay."



New
Amer

Robert Ballard embarks
expedition to discover wh
waves of this country's la

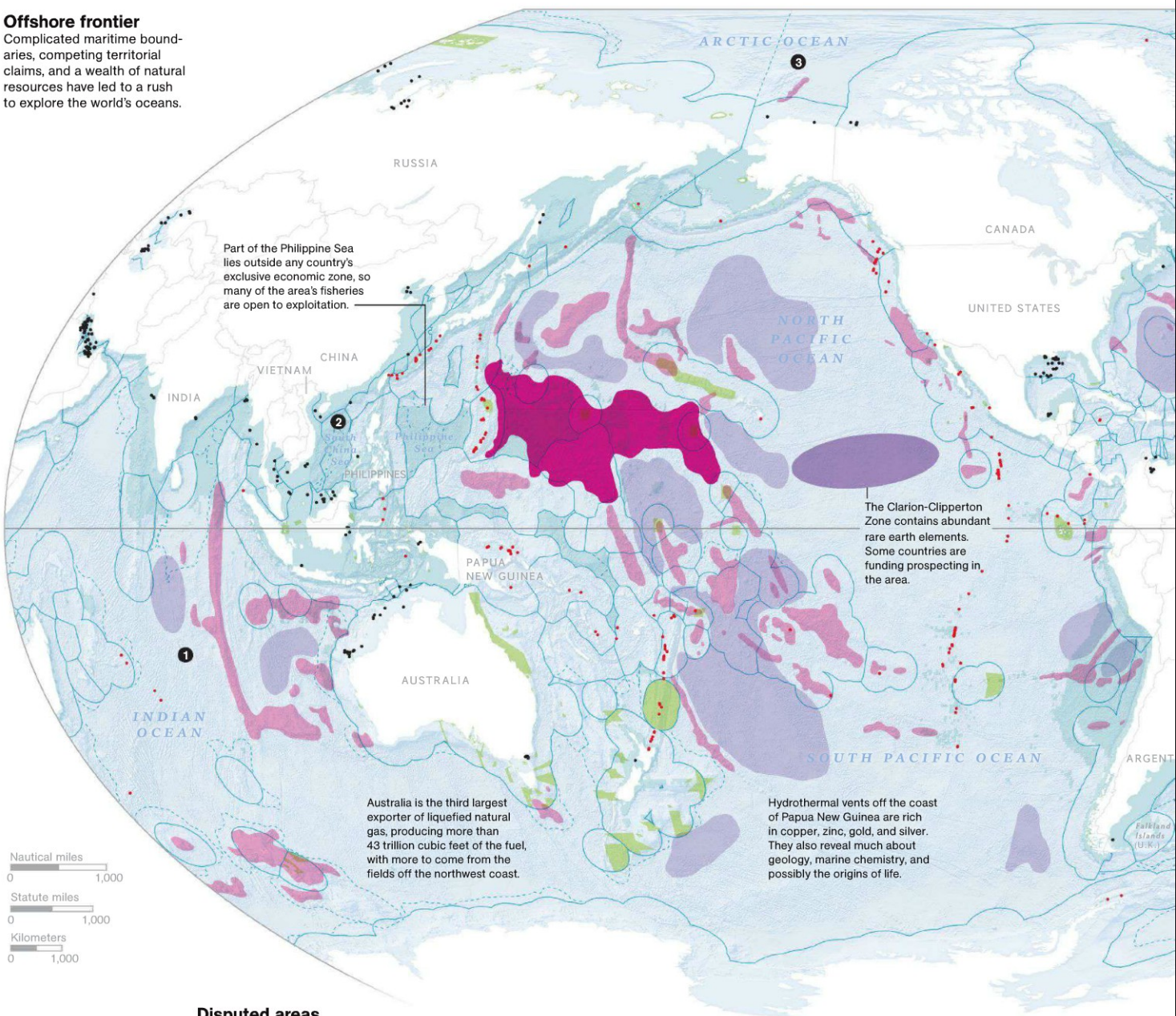


rica

on a ten-year
hat lies beneath the
test frontier.

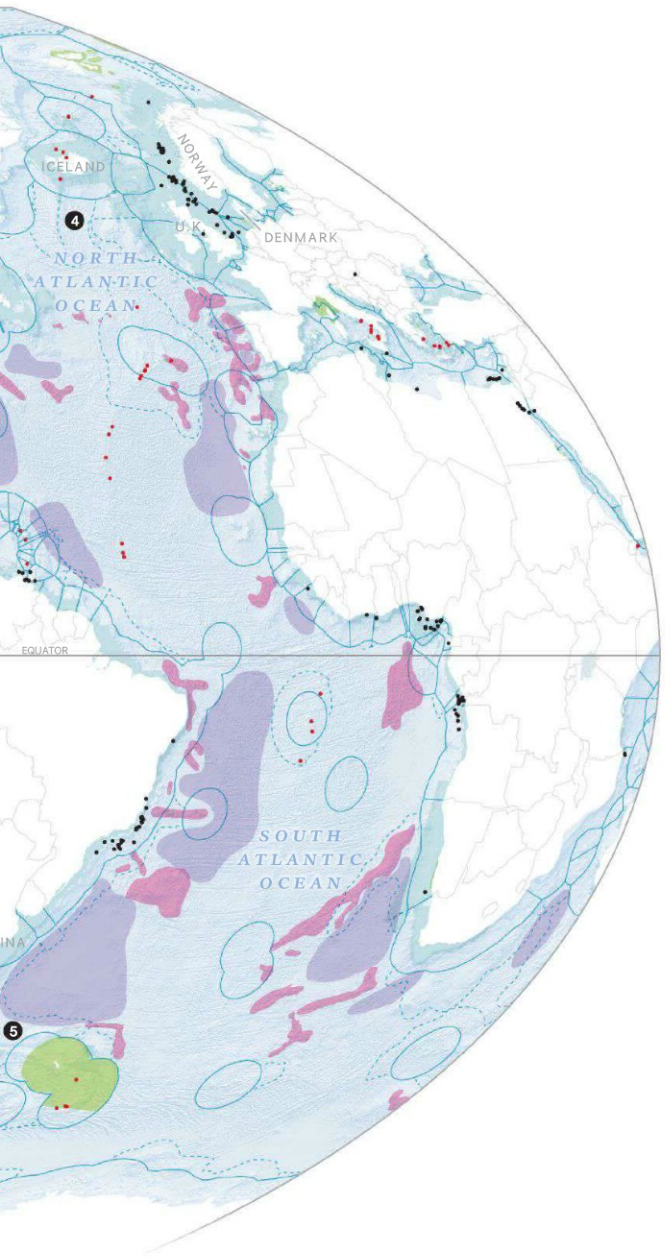
Offshore frontier

Complicated maritime boundaries, competing territorial claims, and a wealth of natural resources have led to a rush to explore the world's oceans.



Disputed areas

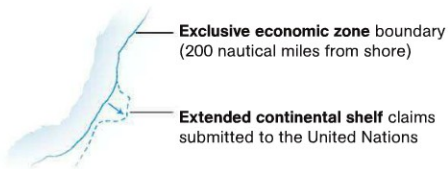
1. **Indian Ocean** China and India have increased naval activity in the region, contesting shipping lanes and potential mineral resources.
2. **South China Sea** China, Vietnam, and the Philippines are at odds over claims to fisheries and rich oil reserves.
3. **Arctic** Russia, the U.S., Canada, Norway, and Denmark all hope to claim portions of this territory and its potentially vast oil and gas resources.
4. **North Atlantic** Iceland and the U.K. have clashed in the past over fishing rights. Now the countries accuse each other of overfishing.



5 South Atlantic Oil fields that could be worth billions of dollars surround the Falkland Islands. The U.K. holds sovereignty, but Argentina objects.

Expanded Boundaries and Hidden Treasures

The United Nations Convention on the Law of the Sea grants all coastal countries sovereign rights to the areas extending 200 nautical miles beyond their coasts, known as the exclusive economic zone (EEZ). These watery properties contain abundant natural resources: large oil and gas reserves, valuable minerals, and teeming fisheries. So does the seabed beyond, where countries can make additional claims if they can prove that the continental shelf stretches past the underwater border of their EEZs and meets other criteria set by the convention. Robert Ballard's Exploration Vessel *Nautilus* and the National Oceanic and Atmospheric Administration's *Okeanos Explorer* are in the midst of a long-term program to discover what riches lie within America's EEZ—and perhaps beyond.



Critical mineral areas Minerals that are rare in the United States but important to the economy and national defense can be found under the ocean in crusts and nodules, which are formed by the accumulation of metals from seawater on rock (crusts) or in mud (nodules).

CRUST ZONES

- **Pacific prime crust zone:** highest concentrations of cobalt and nickel (thicker crust)
- Cobalt, nickel, manganese, tellurium, platinum, and other rare metals, including rare earth elements

NODULE ZONES

- **Clarion-Clipperton Zone:** highest concentration of copper and nickel
- Nickel, copper, manganese, lithium, molybdenum, and rare earth elements

- **Oil and gas fields** with the equivalent of more than 500 million barrels of oil
- **Active hydrothermal vents** with signs of massive sulfide deposits, which might include zinc, copper, gold, and silver
- **Protected areas** where natural resource use is limited, marine species and habitats are closely monitored, or a nature preserve has been established
- **Fisheries** where the annual catch is greater than 500 metric tons

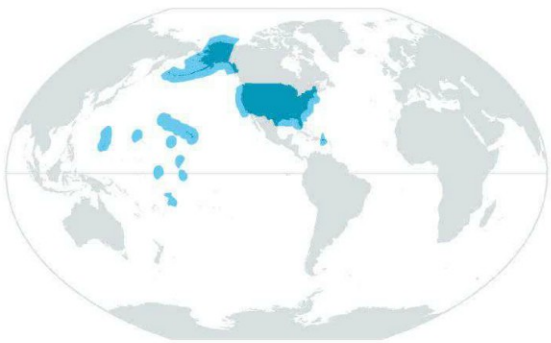
RYAN MORRIS, NGM STAFF; THEODORE A. SICKLEY. SOURCES: NOAA; AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS; JAMES R. HEIN, USGS; INTERRIDGE; BUREAU OF OCEAN ENERGY MANAGEMENT; WORLD DATABASE ON PROTECTED AREAS; IUCN; SEA AROUND US PROJECT, UNIVERSITY OF BRITISH COLUMBIA; UNEP SHELF PROGRAMME; FLANDERS MARINE INSTITUTE

BY ROBERT D. BALLARD

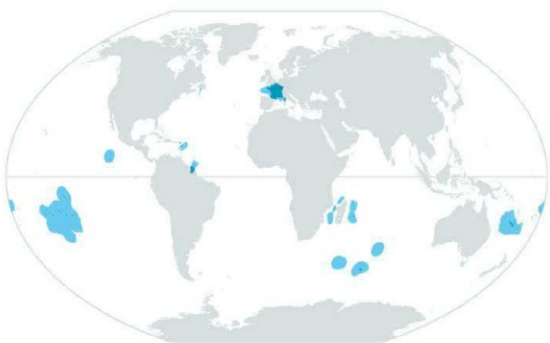
America has had two great ages of exploration. The one that every schoolchild learns about began in 1804, when Thomas Jefferson sent Meriwether Lewis and William Clark on their epic journey across North America. The other one is just beginning. During this new age of exploration we will go farther than Lewis and Clark and learn the secrets of territories beyond even Jefferson's wildest imagination. Yet it seems safe to say that most Americans don't know anything about it.

LARGEST UNDERWATER HOLDINGS

These six countries maintain sovereign rights over more marine area than other nations, due to their lengthy coastlines or empire-building pasts—or both, in the case of the United States.



1. UNITED STATES
4,690,000 sq mi



2. FRANCE
3,930,000 sq mi

Few realize that the single largest addition to the American domain came on March 10, 1983, when President Ronald Reagan, with the stroke of a pen, expanded the country's sovereign rights 200 nautical miles from its shores "for the purpose of exploring, exploiting, conserving, and managing natural resources." By establishing an exclusive economic zone (EEZ), Reagan roughly doubled the area within United States boundaries, as Jefferson had with the Louisiana Purchase.

Other countries have increased their jurisdiction over natural resources through EEZs and are eager to add more. Under the 1982 UN Convention on the Law of the Sea, which the United States has not joined, countries can claim sovereign rights over a larger region if they can prove that the continental shelf—the submerged portion of a continent—extends beyond their EEZ and meets certain other conditions. The United States potentially has one of the largest continental shelves in the world.

A lot is at stake. Just like the land that Lewis and Clark explored, the ocean floor contains natural resources, many of them untapped. Vast oil and gas deposits lie under the waves. So do hydrothermal vents, where copper, lead, silver, zinc, and gold have been accumulating for hundreds of millions of years. By some estimates there are more than 100,000 seamounts containing minerals critical for national defense.

That's not all that lies beneath. These watery

Society Grant This research project was funded in part by your National Geographic membership.

zones encompass fisheries that nations rely on for sustenance, shipwrecks that may reveal lost chapters of history, and habitats that need to be preserved as marine sanctuaries.

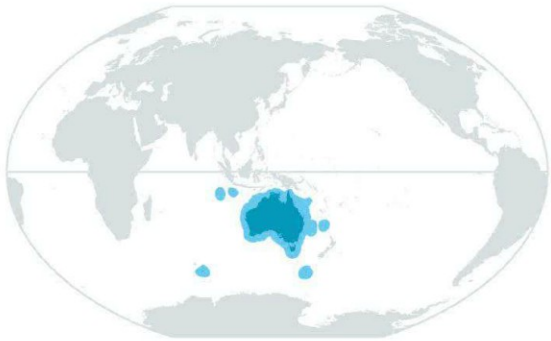
Most of the U.S. EEZ hasn't been explored. In 1803, with the territory from the Louisiana Purchase newly in hand, Jefferson instructed expedition leader Lewis to "take observations on…the soil & face of the country, its growth & vegetable productions…the mineral productions of every kind…volcanic appearances [and] climate as characterized by the thermometer."

Reagan did not follow Jefferson's example. To this day we have better maps of Venus, Mars, and the far side of the moon than we do of much of underwater America.

But now it's time for a new epic journey. Last June the United States' only dedicated ships of exploration launched a joint, concentrated effort to find out what lies within the country's EEZ. The National Oceanic and Atmospheric Administration's *Okeanos Explorer* mapped some of the New England Seamount chain near Rhode Island, among other places, while my vessel—the Ocean Exploration Trust's *Nautilus*—mapped portions of the Gulf of Mexico and the Caribbean. Both ships use multibeam sonars mounted on their hulls, which enable the creation of maps in three dimensions.

Lewis and Clark traveled for more than two years and had to wait until their return home to share their discoveries with an expectant nation. Although the ocean depths plumbed by these modern expeditions are more remote than the land Lewis and Clark charted, we are in constant communication with oceanographers and other experts on shore. The moment a discovery is made, scientists can step aboard either of the two ships virtually, take over operations, and share findings in real time with a plugged-in world. This is a voyage of discovery everyone can make. □

Robert D. Ballard is an explorer-in-residence for the Society. He discovered the Titanic, *the* Bismarck, *the* Yorktown, PT-109, *many ancient shipwrecks, hydrothermal vents, and black smokers.*



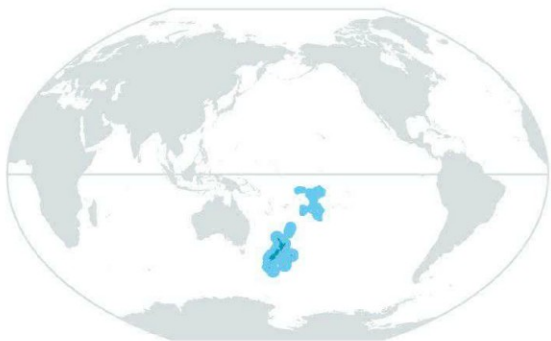
3. AUSTRALIA
3,500,000 sq mi



4. RUSSIA
2,970,000 sq mi



5. UNITED KINGDOM
2,620,000 sq mi



6. NEW ZEALAND
2,590,000 sq mi

MAPS: RYAN MORRIS, NGM STAFF; THEODORE A. SICKLEY
SOURCE: FLANDERS MARINE INSTITUTE

The War for Nigeria

A bloody insurgency tears at the fabric of Africa's most populous nation.

Janet Daniang, 15, bears scars from a 2012 church bombing by the Islamist militant group Boko Haram.





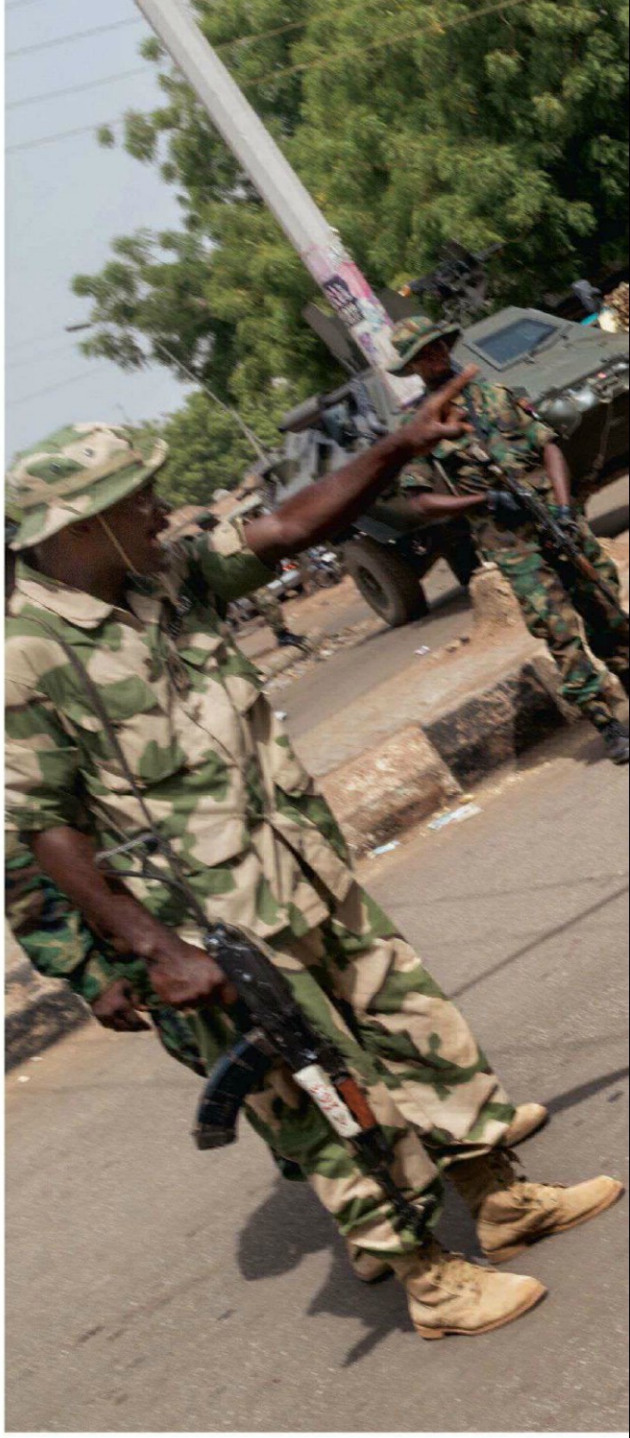
In Kano's Sabon Gari district, where most of the city's Christians live, fear of attack is constant. On Sundays police park water-cannon trucks outside churches to protect worshippers.


RPF6357C
OLICE

In the city of Kaduna people scavenge amid trash heaps. Nigeria is the world's fifth largest oil exporter, but nearly two-thirds of its citizens are abjectly poor. The north, long neglected by the central government, is especially bleak.



BY JAMES VERINI
PHOTOGRAPHS BY ED KASHI



THE TICKET TAKER, who worked at Kano's bus station, had his back to the blast. Before he heard it, it knocked him to the ground, and flame licked his head. He lay face-down, dazed, his ears ringing, blood streaming from a shrapnel wound in his leg, but still he knew instinctively what had happened: There was a bomb in the car.

The driver of the Volkswagen had acted strangely. After pulling into the dirt lot of the station, he and the man in the passenger seat had been approached by touts—ticket salesmen who compete for fares—and had told them, "We don't know where we're going." But when the ticket taker went up to the car, the driver said, "We already bought tickets." Not thinking much of it, the ticket taker walked away.

And then—boom.

As his ears stopped ringing, the screaming grew louder. He got up, and through the thickening black smoke he saw people staggering away from the buses. Burning bodies hung from what had been their windows. Moments before, they had been sleek, new 60-seaters waiting to head to points south. Now they were a pyre, like some awful ancient ritual offering. On the ground around him the ticket taker saw the corpses and remains of passengers, of the touts, his colleagues, the women who sold boiled cassava and roasted fish from plastic tubs carried on their heads. Friends he saw every day were now "separate people parts," as he put it to me.

He looked down at his leg and saw that he too was on fire. Frantically, he pulled off his clothing. Then he made his way out of the lot, one in a crowd of unclothed people stumbling out of the clouds of black smoke billowing from the station. "I walked naked to the hospital," he said. He lost consciousness along the way. Someone, he doesn't know who, carried him on.

The ticket taker came to in a nearby hospital. Then he was transferred to Kano's National Orthopaedic Hospital, where, the following week, I met him. (The hospital's director would not allow me to ask his name.) His ward and two more were filled with victims of the bombing, and their wounds were eerily repetitive. For those lucky enough to have escaped the worst, faces were singed, and skin was missing from arms and waists, stripped off with burning clothing. Those not as lucky were no longer visibly African; the outer layer of flesh had been burned from their bodies, leaving them looking—as some joked to each other, when it wasn't too painful to move their mouths—like *beke*, the



Soldiers force men to the ground at a checkpoint in the city of Sokoto. As feared as Boko Haram in the north, security forces harass and detain people on scant evidence and likely have killed as many Nigerians as the rebel group has.

Igbo word for a white man. It was as though their identities had been taken.

One such man sat on his bed staring at the wall in an effort to withstand the pain, while nurses wrapped him in gauze. He turned and looked at me with an expression of such kindness that I smiled. I asked—the stupidity of my question apparent immediately—"Are you OK?"

"No," he said calmly, and returned to staring.

WHEN THE CAR EXPLODED, the same two words occurred to him, and to the ticket taker, and to every other person who saw or heard the blast, which could be heard on the other side of Kano, Nigeria's second largest city: Boko Haram. That neither they, nor practically anyone else in Nigeria, knew what Boko Haram was exactly or why it would want to bomb a bus station was beside the point.

Officially, according to the Nigerian government, Boko Haram is a terrorist group. It began life as a separatist movement led by a northern Nigerian Muslim preacher, Mohammed Yusuf, who decried the country's misrule. "Boko Haram" is a combination of the Hausa language and Arabic, understood to mean that Western,

James Verini wrote about Gaza's tunnels in December 2012. Longtime contributor Ed Kashi has spent years documenting Nigeria's oil industry.



These survivors of a March 2013 bus station bombing in Kano were treated in city hospitals. Many of the dead were incinerated. Estimates of their numbers vary widely, but few believe the government's toll of 22.



or un-Islamic, learning is forbidden. In 2009, after Yusuf was killed—executed, it's all but certain, by Nigerian police—his followers vowed revenge.

The world is coming to the unwelcome realization that, 12 years after 9/11, violent Islamist extremism and the conflicts it ignites aren't going away. Accompanying that is the equally unwelcome realization that these conflicts afflict, more than ever, Africa, a continent still unequal to the challenges of the 20th century, never mind this one. In the Sahel, home to al Qaeda in the Islamic Maghreb and to the jihadists who until recently controlled northern Mali, Boko Haram has emerged as the nastiest of a nasty new breed. Calling for, among other things, an Islamic government, a war on Christians, and the death of Muslims it sees as traitors, the group has been connected with upwards of 4,700 deaths in Nigeria since 2009. And although Nigeria, with 170 million inhabitants, is the continent's most populous country (one in six Africans is Nigerian) and has sub-Saharan Africa's second largest economy, even by its immense standards the carnage attributed to Boko Haram is immense.

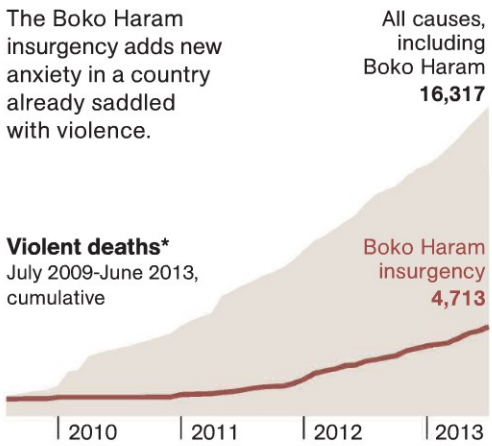
So much so that unofficially, in the national collective consciousness, Boko Haram has become something more than a terrorist group, more even than a movement. Its name has taken on an incantatory power. Fearing they will be heard and then killed by Boko Haram, Nigerians refuse to say the group's name aloud, referring instead to "the crisis" or "the insecurity." "People don't trust their neighbors anymore," a civil society activist in Kano told me. "Anybody can be Boko Haram." The president, Goodluck Jonathan, an evangelical Christian, wonders openly if the insurgency is a sign of the end times.

AFTER THE BUS STATION bombing I twice traveled to Atakar, a hilly area in Kaduna state, where mass killings had been reported. Before the first visit I consulted officials. They hadn't gone to Atakar and wouldn't, because they believed Boko Haram was behind the killings. Everyone killed had been Christians, they assured me. "It's not unconnected with the quest for the Islamization of the north," one official said. "They want as much as possible to annihilate the Christians."

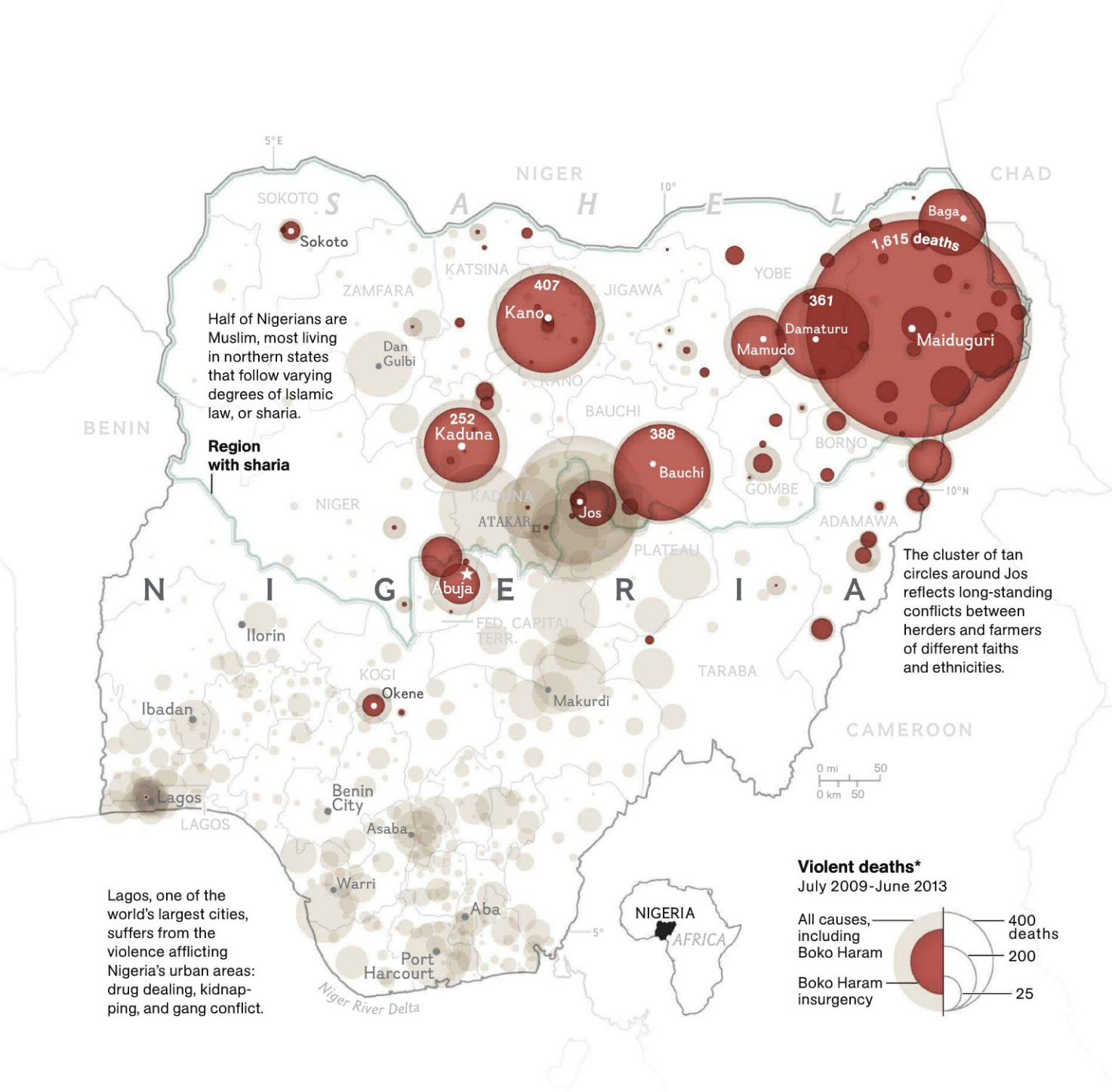
In the first village I visited, I met a family huddled by their roofless, charred homes. They were, in fact, Fulani Muslims, and they claimed they'd been attacked by marauders from the other side of Atakar—Christians, they presumed. Some of them said the attack had been ethnically motivated, others religiously. A young man told me that the original incitement had to do with a poisoned cow. "We were attacked because we are Fulani—and because of the cow that died," he said. He wasn't being facetious: Northern Nigeria has endured decades of ethno-religious slaughter, often enough touched off by peccadilloes.

Nigeria's Insurgent North

Boko Haram rebels aim to make northern Nigeria an Islamic state. More than 4,700 people have died in violence that first erupted in 2009 in the northeast city of Maiduguri. Half have been killed in Boko Haram attacks on government institutions, churches, and secular schools. An equal number, many with no ties to the terrorists, have died in government counterattacks.



*Deaths are estimates based on Nigerian media reports and include Boko Haram splinter groups and government response.



In 2002, after a journalist remarked that the Prophet Muhammad would have approved of a beauty contest, riots left hundreds dead.

Later I traveled to the other side of Atakar and found that villagers there, Christians from the indigenous Ataka tribe, had also been attacked. They'd assembled in a refugee camp in a schoolyard. One man told me that he was in his home when he heard gunfire. He went outside and saw men dressed in black shooting "powerful guns." He barely escaped with his life, he said. He was certain the attackers were Fulani, as was a neighbor who joined our conversation. When I asked the neighbor why, he said, "My people don't wear black." Both suspected the attackers were also Boko Haram, though why that group would want to assail this remote place they couldn't say.

"We want to believe it's Boko Haram," a local aid worker told me, in such a way as to denote that life had become so incomprehensibly frightful in northern Nigeria that wanting to believe Boko Haram was involved was enough to make it so. "We don't have any other information," he said, expanding on the thought, "so we want to believe it's Boko Haram."

IN HIS AUTOBIOGRAPHY Ken Saro-Wiwa, the son of the Nigerian activist of the same name who was executed by the state on trumped-up charges in 1995, writes that "Nigeria should be

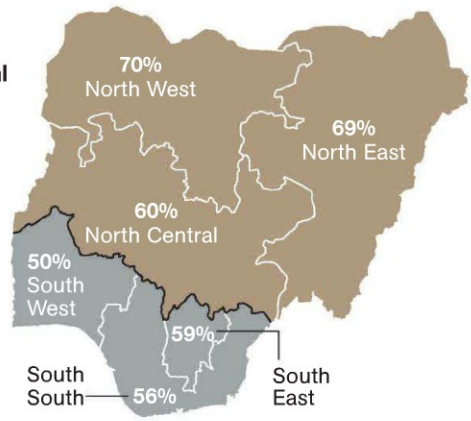
MAGGIE SMITH AND ALEXANDER STEGMAIER, NGM STAFF; LAUREN E. JAMES
SOURCES: NATE HAKEN, FUND FOR PEACE AND PARTNERS FOR PEACE; NIGERIA WATCH; MICHAEL WATTS, UNIVERSITY OF CALIFORNIA, BERKELEY

A Deepening Divide

Few Nigerians support the radical aims of Boko Haram, yet few challenge its charge of government corruption. The free elections held since 1999 have been tainted by violence and fraud. Meanwhile Nigeria's failure to equitably distribute billions of dollars in oil income undermines the resource-poor north, threatening the nation's stability.

POVERTY
One percent of Nigerians are wealthy, and there's an educated middle class. But nearly two-thirds of people live in absolute poverty, a greater percentage in the more agricultural north than in the south.

Poverty level by geopolitical zone,* 2010



God's own country in Africa." This could be dismissed as just more of Nigeria's famous nativist braggadocio if its neighbors and its despairing partners in the West didn't agree. That braggadocio—and a fierce ambition—are matched by the country's resources, among them gas, minerals, good harbors, and fecund soil that once helped propel the British Empire. Nigeria boasts an educated middle class, industrious cities, a rowdy, if not exactly free, press.

The most lucrative of its resources, however, since its discovery in the 1950s, is crude oil. Nigeria is the world's fifth largest exporter; yet nearly two-thirds of its citizens live in absolute poverty, meaning that they have just enough to not die. Oil has made government the best business venture in Nigeria, and because oil, and not taxes, accounts for most of the state's revenue, it also makes politicians unanswerable. A newspaper last year estimated that since President Jonathan entered office in 2010, $31 billion have disappeared. "There's been a failure of government at all levels historically in Nigeria," a Western diplomat working there told me.

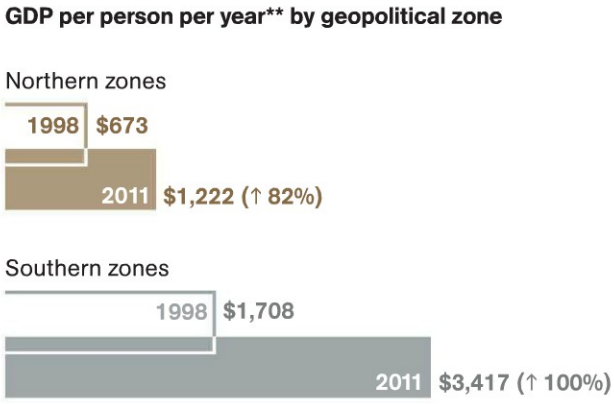
This failure is everywhere apparent, but nowhere as much as in Kano, once one of the great cities of Africa and of the Muslim world. Islam arrived with merchants and clerics in the 11th century (giving it a much longer history there than Christianity); the Hausa king of Kano adopted it in 1370. In 1804 a caliphate was established. The British toppled it in 1903 but retained its pliant emirs. Kano, the heart of regional trade since antiquity, became an industrial and agricultural hub. So well was the arrangement working for him, the Emir of Kano opposed Nigeria's independence, gained in 1960. A half century later roughly half of Nigerians are Muslims, the vast majority living in the north.

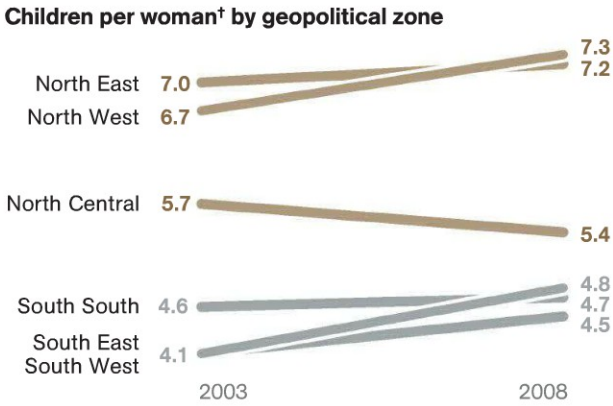
The emir and the British kept out Western education and other advances but allowed in Christians from the south. Kano's fortunes began to slide in the 1970s, and as they did, its lack of development—and the lack of oil in the north—grew more apparent. Current statistics are unnerving: More than half of children under five in northern Nigeria are stunted from malnutrition. In the northeast, where Boko Haram started, only a quarter of homes have access to electricity, which would be a bigger problem if more than 23 percent of women could read. In the 1980s, 1990s, and again in the early 2000s ethno-religious conflicts killed thousands. Then Boko Haram came in.

*Nigerian government classification. **Constant 2005 PPP dollars. †Age 15 to 49.

UNEVENLY SHARED RESOURCES
Almost all of Nigeria's budget and foreign exchange comes from oil tapped in the south's Niger River Delta. Wealth not siphoned off by corruption benefits mainly the south, fueling resentment in the north.

YOUTH SURGE
Sixty-three percent of Nigerians are under age 25. High fertility rates have led to a large youth population in the north, where economic growth lags and job shortages are a source of tension.





Today Kano feels like a weary garrison. Approaching it, you come to checkpoints every few hundred yards. Between them you pass farms left fallow by neglect and desertification and through the half-alive villages they used to support. In the city, urban desertification: streets, parks, plazas empty. Signs are gone from any place deemed vulnerable to attack, which, since the bus station bombing, is any place. At police headquarters the only notice, spray-painted on an exterior wall, instructs, "Do Not Urinate Here."

The most visible figures of authority in the city, the only visible figures of authority, are the Joint Task Force units (JTFs)—paramilitary teams made up of police, soldiers, and agents from the State Security Service, Nigeria's equivalent of the FBI, who patrol in reptilian armored vehicles and canopied pickups. They're known for their brutality and venality and have become as feared as the insurgents in some quarters, particularly in poor Muslim districts.

The real power in Kano is hidden, conspicuously. Behind tall walls in the city center is the state government's sprawling seat. In his office there, the governor, Rabiu Kwankwaso, greeted me from an archipelago of leather sofas. On one wall was a life-size painting of Kwankwaso; against another, a life-size stand-up cardboard cutout of him. In both he was wearing exactly what he had on when I met him: a white *babban riga* robe and red brimless cap, emblems of his Kano revitalization campaign, which he calls the Red Cap Revolution.

"I have no doubt in my mind that one day Nigeria will overcome it," Kwankwaso told me, referring to Boko Haram. "How it will happen, it is difficult to say now." A trio of aides nodded. "This is the time to listen even to foolish people, to hear what they are saying, because we don't have answers." Kano hasn't upgraded its power grid in years, and as he talked, the lights went out. They came back on, and he continued. "You have to prevent violence. On the other hand, government has to do so many other things. What we are seeing is just a symptom of what has happened in the past." After Kwankwaso's first term in the governor's office ended in 2003, he was indicted for embezzling $7.5 million in state funds. He was not prosecuted and in 2011 was elected again.

In Kano's old walled city is the emir's palace. Amid the poverty of his subjects, the emir, now 83, still lives very much like an emir. I wasn't granted an audience with him, but one morning I was invited to look around the palace, a

JOHN TOMANIO AND ALEXANDER STEGMAIER, NGM STAFF
SOURCES: MICHAEL WATTS, UNIVERSITY OF CALIFORNIA, BERKELEY; NIGERIAN NATIONAL BUREAU OF STATISTICS; CANBACK DANGEL



Bridesmaids go over the ceremony program before a wedding at the Evangelical Church Winning All in Sabon Gari. Although an embattled minority, Kano's Christians still worship and celebrate with flair.





Judge Ibrahim Yola hears a land dispute case at City No. 3 Sharia Court in Kano. In 2000, state governments in Nigeria's predominantly Muslim north instituted sharia courts alongside state courts to address criminal matters.


HON. GRAND KADI
ALH. DAHIRU RABI'U

"There's been a failure of government at all levels historically in Nigeria," a Western diplomat working there told me. This failure is everywhere apparent, but nowhere as much as in Kano.

rumpus of alcoves and anterooms. I arrived alongside a busload of Gulf-state visitors filing in with gifts in duty-free bags. After convening with them, the emir emerged in a meringue of robes, mounted a horse, attendants shielding him with a giant, tasseled umbrella, and rode to his mosque. It used to be that anyone could come and watch these rituals. That ended in January, when men drove up alongside the emir's Rolls-Royce, pulled out guns, and opened fire. Two of his sons were shot, several of his entourage killed.

The assurance of violence hangs in the air. While I was in Kano, there were near-daily reports of shootings and a series of botched bombings, including one at the palace. On Sunday mornings police park water-cannon trucks outside churches, and preachers inside talk about the "Lord's battle" against Boko Haram; in nearby mosques clerics condemn Goodluck Jonathan's "war on Islam." On Easter a TV reporter friend of mine got a call. JTFs had raided a suspected Boko Haram hideout. He returned a few hours later with familiar footage: an orderly array of guns, bullets, and homemade bombs, and near it an orderly array of bodies of slain "militants." Among the dead on this day I could see at least one woman and a child. The position of the bodies suggested that the people had either been piled together after being shot or were killed en masse.

THERE ARE VARIOUS CREATION stories for Boko Haram. The most common I heard in Nigeria is this: In the early 2000s in the northeastern city of Maiduguri, Mohammed Ali, a preacher fed up with poverty and disorder, embarked on a hegira, a Muhammadan withdrawal from society. He and his followers created a commune and practiced sharia. After a dispute with authorities, the Nigerian Taliban, as they'd become known, attacked a police station. The army laid siege, and Ali was killed.

Survivors regrouped around a promising contemporary of Ali's, Mohammed Yusuf. Yusuf built a bigger commune, described in a report as a "state within a state, with a cabinet, its own religious police, and a large farm." He called his group Jamaa Ahl al Sunna li al Dawa wa al Jihad, or People Committed to the Propagation of the Prophet's Teachings and Jihad. Possibly deriding Yusuf's religiosity, someone called it Boko Haram. Yusuf was carrying out forced conversions to Islam, according to reports, and likely ordered the murder of a rival. Nonetheless he gained sympathizers around Nigeria, not all of them Muslim. "Boko Haram is a resistance movement against misrule rather than a purely Islamic group," one bishop said. Yusuf, a Maiduguri reporter told me, "was so charismatic. He could talk to people very gently, very simply," but "when he preached, he acted. Overacted."

In 2009 Yusuf's followers clashed with security forces. The army shelled the commune. Yusuf had predicted that if he was ever arrested, he would be killed without trial, and that's exactly what happened. Surviving devotees went into hiding. Some traveled abroad for training with other militants, and some regrouped in Kano around Abubakar Shekau, Yusuf's deputy. They set out to "liberate ourselves and our religion from the hands of infidels and the Nigerian government." Northern Nigeria was overtaken by bombings, arsons, and shootings—at police stations and government offices, then at churches, mosques, schools, and universities—and by assassinations of officials, politicians, clerics, and others. The federal police headquarters in Abuja was suicide-bombed, then the UN compound. A residence of the vice president's was shot up.

A deadly attack hit Kano on January 20, 2012. Waves of gunmen set upon police stations and State Security Service offices. The official estimate of the dead was 185, but according to Kano residents I spoke with, the real number was much

larger. I was also told that some people risked their lives to gather outside police stations to cheer on the attackers, so despised are the authorities in Kano.

THE RESENTMENT THAT IMPELLED those residents is summed up in a favorite saying of Ken Saro-Wiwa's, which his son likes to quote: "To live a day in Nigeria is to die many times." The smallest tasks in Nigeria sap one's dignity. En route to Kano, I flew through the Lagos airport, where the guard at the bag scanner shook me down for a bribe in front of his expressionless superiors. I refused. He negotiated: "Money for water?" I told him that if he really was thirsty, he could meet me in the snack bar. A half hour later he arrived, uniform gone, now in natty denim, two mobile phones in hand, and leaped into a chair with a "Here you are!" We talked for an hour. I ended up buying him water and lunch. He in turn called a friend who picked me up at the Abuja airport. "Anything you need," the guard said as we parted, and he meant it.

Such is the polyphony of interaction in Nigeria—"affectionate extortion," I heard it called. In a country that's endured a civil war, six military coups, two assassinations of heads of state, and at least three crippling domestic insurgencies in just over 50 years of existence, and where contempt for leadership has hardened into a perverse kind of civic responsibility, this mixture of menace and generosity, officiousness and humor—the attitude that allows a man whose skin has been burned off to joke that he's been turned white—is indicative of a certain flippancy, part of that Nigerian braggadocio. It's also a way of keeping sane. And to that end it orders Nigerians' complex perspective on sedition. They condemn Boko Haram and see its hypocrisy. As one soldier, a Muslim, said to me while guarding a church on Palm Sunday, "They say Western education is wrong. But that book you're reading, how was it made? That pen you're using, how was it made? That gun you have, where was it made?" But they pay Boko Haram a grudging deference too. They know well the frustration that would drive someone to take up arms against the state.

This deference takes subtle forms. On Kano street corners vendors sell DVDs of insurgent attacks downloaded from the Internet. Saying Boko Haram aloud is discouraged, but you can refer to the Boko Boys, or BH, as though it were some hot rap act.

The extent of the insurgency's strange effects on the Nigerian psyche became apparent as I looked into the bombing at the bus station. Unlike Boko Haram's signature attacks, this one was indiscriminate, meant to kill as many as possible, whoever they were. But theories about its meaning vary. Kano is majority Hausa and Fulani, but Sabon Gari, the district where the station is located, is home to many Igbo. They tend to be Christian, and they operate the bus lines. So the most widespread theory is that the bombing was an attack on Igbo Christians. "To me it's an extension of killing Christians in their churches," a security officer in Abuja told me. A traditional Igbo leader in Sabon Gari who goes by Chief Tobias said, "Igbos were the target."

But this theory goes only so far. The bus operators are Igbo, yes, as were many of the passengers and station workers who died. But many others were not. Some were Hausa or Fulani, some, possibly, Kanuri, the majority ethnicity of Boko Haram's originators. Sabon Gari is home to most of Kano's churches, but it also has many mosques. It is the most diverse part of Kano, a throwback to the city's old cosmopolitanism, and on a given day any number of the 250 or so ethnic groups that make up Nigeria might be represented there.

A prominent former Kano parliamentarian, Junaid Muhammad, a Muslim, told me that Chief Tobias's claim was ridiculous. "You cannot tell your bullet or your bomb, 'Go and hit an Igbo man' or 'Go and hit a Hausa man.'" I went to see Boniface Ibekwe, the supreme leader of the Igbo in Kano and a Christian, and was surprised to find he agreed. "It's not a direct attack on Igbos," he said. "Boko Haram's objective is to get where people are gathered together and destroy it."

Some people believe the bus station was bombed because it is a center of commerce. It represents the influx of foreign goods, foreign ideas, impious ideas. Others wonder if the

Men drove alongside the Emir of Kano's Rolls-Royce and opened fire. Two of his sons were shot, several of his entourage killed. While I was in Kano, there were near-daily reports of shootings.

bombing was meant to protest the economic dominance of the south over the north. Perhaps what Boko Haram really wants, one theory holds, is regional equity or a new northern nation. Among northern politicians, secession is an oft talked about, if impracticable, idea.

One thing everyone seems to agree on is that when the authorities got involved, the confusion increased. Take what ought to be the most basic fact: how many died. I spoke to one reporter who put the total around 30; another said around 40. Chief Tobias said 75. The real number will never be known, because no official account of the incident has been given. The government's tally—22 dead—is a fiction.

The government won't say who it suspects the bombers were, aside from Boko Haram; how the car bomb was made; or even whether there was only one bomb. Some witnesses claim there were two. Most people agree the car was a Volkswagen, but some—including the ticket taker—say it was an Opel. Some witnesses claim there were two people in the car, others three. According to local journalists, security forces removed corpses from the station as quickly as possible and moved survivors from one hospital to another in an effort to keep reporters away from them. The authorities "don't want the public to know what is actually happening," Nasir Zango, a Kano reporter, said.

Why? There are varying theories about that too. To head off reprisal attacks. To protect their jobs. Because they deceive a lot. The most common explanation offered to me, and the most troubling, is that security forces didn't properly investigate the bombing because they can't. They don't have the training or the experience, not to mention the interest. They don't have the equipment to analyze bomb fragments or the intelligence networks to lead them to the bombers. Often police don't even bother taking statements from witnesses after attacks, I was told.

Still, the government and the press are equally quick to pin any violence in the north on Boko Haram. For the former, it distracts from mendacity and ineptitude. For the latter, it provides copy. Privately many people agree that criminals have found in Boko Haram a perfect cover. The result of all this no longer stops at confusion. "You begin to think it's as though someone's hell-bent on seeing these problems continue," Lawan Adamu, another Kano reporter, said. "The conflict, the crisis, is taking a very big dimension that is really making many of us start thinking or believing that there is a conspiracy. Many people have said this before, and I didn't want to believe, but now I'm starting to."

Ken Saro-Wiwa the younger, who now is (in a perfect Nigerian irony) an adviser to President Jonathan, told me that Boko Haram is "typically Nigerian, in that it started as an ideological movement. Then it was co-opted by political opportunists. Then it was mixed with economic issues. And now it's muddied, so that you can't tell what it's about."

When I asked a local community leader in Atakar why no state officials had come to the attacked villages there, he said, "Why would they come? They are the sponsors of these things." And was Boko Haram involved? "Why not?" he said. "What is the difference?"

It was a sentiment I heard again and again. Almost no Nigerian I spoke with believes Boko Haram is just Boko Haram. Some claim it's the creation of Wahhabis from the Gulf states; others, of "the West." Still others believe Boko Haram is backed by northern politicians vying for power; or by southern politicians who want to destabilize the north; or by people in President Jonathan's party who want to unseat him; or by Jonathan himself, in an effort to cancel elections in the north; or, if not by him, by the people around him. In fact, Jonathan apparently believes the last. In a moment of unbuttoned paranoia at a church service last year he said,

"Some [Boko Haram] are in the executive arm of government, some of them are in the parliamentary/legislative arm of government, while some of them are even in the judiciary. Some are also in the armed forces, the police, and other security agencies."

And some Nigerians say that Boko Haram doesn't exist at all. "We believe Boko Haram is a political expression," Chief Tobias said. "We don't believe there is an organization Boko Haram."

As I continued reporting, it became apparent that the insurgency's gravest toll on Nigeria isn't physical. It's existential. Boko Haram has become a kind of national synonym for fear, a repository for Nigerians' worst anxieties about their society and where it's headed. Those anxieties touch on the most elemental aspects of Nigerian life—ethnicity, religion, regional inequities, the legacy of colonialism—and not least is the anxiety that Nigerian leaders are wholly incapable of facing this insurgency, indeed unwilling to face it, much less the social fissures beneath it. Or worse, that the leaders are no better than the insurgents. That the state is Boko Haram.

IT'S NOT AN ENTIRELY unreasonable supposition. Of the more than 4,700 killings associated with Boko Haram to date, almost half have been at the hands of security forces, according to Human Rights Watch. Many of those killed have been civilians who were just in the wrong place at the wrong time. As the insurgency gets more vicious, so does the government. In July suspected Boko Haram militants set fire to a boarding school in Mamudo, killing 42 students and teachers. In April the military assaulted the village of Baga, claiming militants were hiding there. At least 200 were killed. Witnesses described soldiers gunning down people as they ran from their homes.

I interviewed people in Kano who claimed they'd been harassed, beaten, or shot by security forces. In my last days in Nigeria I went to Abuja, where I recounted their stories to a general, one of the main architects of the campaign against Boko Haram. He wasn't moved. In fact he wouldn't concede that there had been any abuses. When I pressed the point, he began yelling and pounding his desk. He said such stories were invented by journalists sympathetic to Boko Haram, including, he intimated, me. "We know there are some journalists deliberately siding with Boko Haram in this war!" said the general, who did not want to be named. "I have found some journalists, and they confessed to me they were deliberately siding with certain sides. Deliberately! Some based in Western countries."

Calming down, he went on, "Look, it's a shadowy war we are fighting." To prove how shadowy, he showed me a video found in a raid. It showed Abubakar Shekau. Bushy-bearded, muscular, with a bit of a gut and a limp, the Boko Haram leader is training three young men to wield an AK-47. They're in the closed courtyard of a residential building somewhere, maybe Kano. Children can be heard playing inside. Suddenly there's a knock at the gate. Shekau lurches to a wall, as one young man lifts the rifle unsteadily, ready to fire. A man comes in, carrying a shopping bag. They know him. Everyone laughs with relief.

"You see, they could be anywhere, anywhere!" the general said. "Not only in the north—in the whole of the country! [Nigerians] still don't understand the challenge—the real challenge—we're facing, the seriousness of the situation. They don't understand."

As he said this, I thought back to the hospital in Kano and to a woman I met there. She'd been selling water in the bus station the day of the bombing. Her young daughter had been helping her. When the car exploded, the girl vanished. In the darkness the woman called out for her. When her daughter didn't respond, she began looking for a body. When she couldn't find a body, she looked for an arm, a leg, clothing, a shoe, anything. She found nothing. She told the police what had happened, but they didn't care and ordered her to leave. The woman's husband went to every hospital in Kano, to no avail.

"I never saw my daughter since that day," she said. Dominant in her cracking voice as she said this were grief and confusion. But when she spoke of the police, another note took over. It was anger. □



Since an attempt on his life in January, the Emir of Kano, a revered Islamic figurehead, has mostly kept to his palace. A century after the British overthrew a Nigerian caliphate, its trappings remain.


الحمد لله
امير كنو الحج
عبد الله بيرو

The city of Kano has seen decades of ethno-religious violence. There, as elsewhere in the long-tense north, Islam and Christianity, past and present, meet head-on.





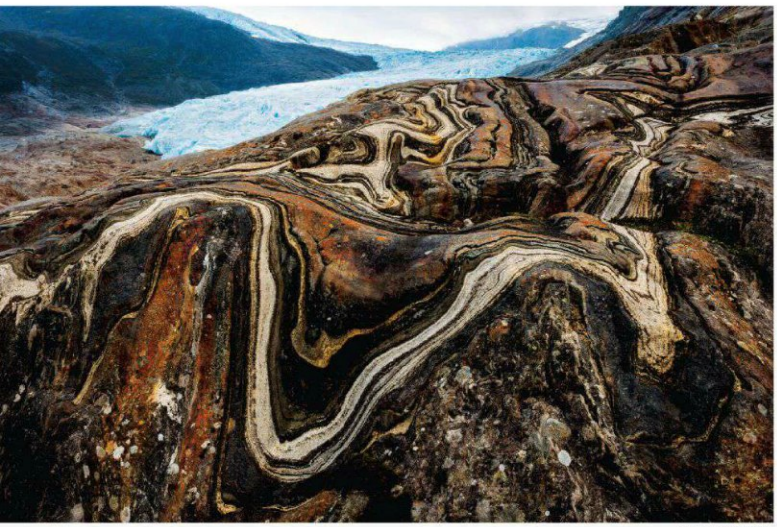

Journey to the heart of



Norway Follow the water

Walled in by the towering peaks of Norway's Lofoten Islands, Kirkefjorden seems a world unto itself.

ORSOLYA HAARBERG

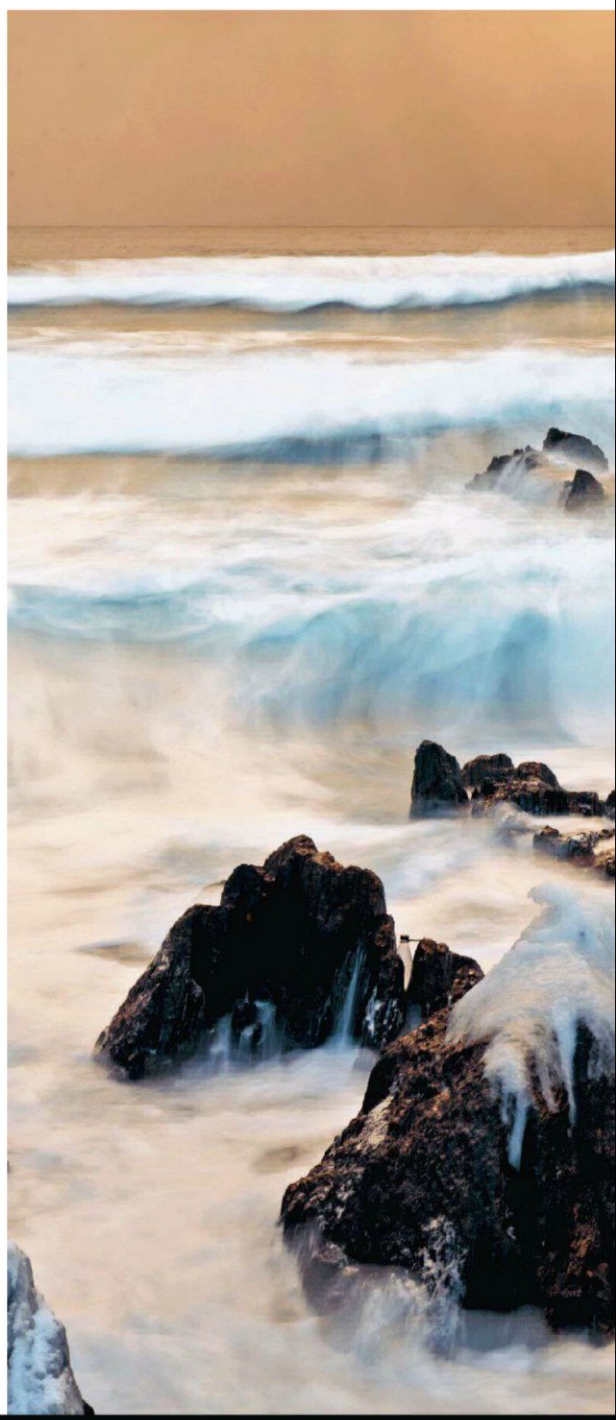


ERLEND HAARBERG



ORSOLYA HAARBERG (ABOVE AND RIGHT)

In the far north of Norway, icy surf and copper-colored snow clouds create an otherworldly scene along the winter coast of the Varanger Peninsula (right). Farther south, near the edge of Engabreen glacier (top), the contortions of time are visible in the sinuous infolding of stone. A jagged porthole in Engabreen (above) frames a view of a nearby peak.







SCALE VARIES IN THIS PERSPECTIVE.

ALEX TAIT AND VICKIE TAYLOR,
INTERNATIONAL MAPPING

By Verlyn Klinkenborg

Photographs by
Orsolya Haarberg and
Erlend Haarberg

Bird cries seem to claw at the bright summer sky. The birds themselves—puffins, gannets, gulls, guillemots—whirl in a tumult around the bluff islands rising from the water. We have put to sea about as far north as you can put to sea, off the uppermost cape of coastal Norway, high above the Arctic Circle. The boat pitches and heaves in the rockbound channels, and I rediscover an old truth. Seabirds are good at flying and floating, swimming and diving, and almost nothing else. They run across the saltwater until it seems they'll never get aloft, and they land like heavy raindrops on the foamy spill from a crashing wave.

But while airborne, surveying these waters with cocked heads, they're the masters of this ragged shore, these broken islands along the northern fringe of Norway, which fits like a skullcap over Sweden and Finland. Here, and eastward toward Russia, Norway meets the ocean bluntly, hills scraped bare, protruding fistlike into the Barents Sea. No one knows the whole of the Norwegian coast, and among its lesser known reaches is the edge of the Varanger Peninsula, which ends at a point farther east than St. Petersburg. It is a low, rimy strand studded with ancient boulders, a world away from Bergen and bathed in copper light among the endless archipelagoes where the fjords run out to sea.

You could, of course, drive from Bergen to Vardø, at the eastern point of the Varanger Peninsula. But a glance at a map or a set of nautical charts makes it clear that a car is just an encumbrance here. For the past 120 years vessels of the famous Hurtigruten (literally, "swift route") have provided a lifeline linking isolated communities to the larger world. Traveling aboard this coastal express, miles make no difference—and at the height of the midnight sun, hours make no difference either. You tell time by the progression of ports: Bodø, Svolvær, Tromsø.

Taken all in all, south to north, the coast of Norway may be the most complex land edge on the planet. In 2011 Norwegian geographers completed a three-year project to recalculate the length of their coastline. Using new techniques and better maps, they added thousands of islands and islets that had never been included in the total before. In all, Norway's measured seashore grew by some 11,000 miles. If you hammered Norway's 63,000 miles of fjords, bays, and island shores into a single line, it would circle the planet two and a half times. All that in a country less than 1,100 miles from south to north.

The coast of Norway may be the most complex land edge on the planet.

Whether you stand on the terminal heights above Geirangerfjorden, looking down into its yawning blue deep, or in the bow of a small boat besieged by seabirds, it's hard to say whether the sea is encroaching on the Norwegian landmass, or the land into the body of the sea.

The water may look more continuous than the land, but it is certainly no simpler. To travel the Norwegian coast is to glimpse an endless discontinuity between land and water, the restless inventiveness of eons of ice. Miles inland, in the heart of Norway's longest fjord, Sognefjorden, the water deepens to 4,000 feet only a few hundred yards from shore. Farther north, cod-drying racks and tight red boathouses look out over water that is hundreds of feet deep. And yet among the outermost islands in the Lofoten

On a velvet sky stippled with stars, the aurora borealis paints bold strokes above Flakstad Island.

ORSOLYA HAARBERG

chain—a broken tusk of snow-covered peaks thrusting into the Norwegian Sea—the water shoals away slowly, only a few feet deep, as if these islands rose no higher than the back of a blowing whale.

Maps of the Norwegian Sea show a strong current—an extension of the Gulf Stream—bearing northward along the coast. These are relatively warm waters, the kind that make human life bearable as far as 70° north latitude, well above the Arctic Circle, as far north as the northernmost tip of Alaska. But what looks on the map like a steady current is actually a chaos of meanders and eddies, wandering and interweaving. If you set yourself adrift in a boat, a graceful, traditional *færing* perhaps, you might be driven onto a strandflat—an etched surface of bedrock barely rising above the waves—or wind endlessly in and out among the skerries near the mouths of the great western fjords. You might careen out to sea only to swirl in again, caught in the eddy revolving below the Lofoten Islands. Catch the right current, and you would spin into the Barents Sea, like a diatom drifting northward and eastward, enriching the island-strewn gannet waters before sinking to the seabed.

From the deck of a working vessel, it looks as though little has changed along the northern coast since a voyager named Ohthere made his way up and into the Barents Sea in the late ninth century. He called the country "weste land"—Old English for "wasteland," meaning unsettled, though coastal Sami were living there then, as they do today. The land still looks wild and wave battered, as if it were rising rapidly (as it is, in geological terms) and shaking off the sea. Well offshore, you can understand the affinity that Norwegian explorers like Roald Amundsen and Fridtjof Nansen felt with the sea. And inshore—watching still water mirror the pilings in Tromsø harbor—you can feel how domestic the sheltering hills are. In this seabooted country, nearly everyone is bilingual, speaking equally the language of earth and ocean.

And so nearly everywhere there is still a certain ceremony in the coming of the Hurtigruten, which is one of the ways time is told in the most remote ports. It may be 3 a.m., but people will be waiting for the ship to dock in the long shadow of the midnight sun. Some have business here in the wharfside warehouses, but some have come just to watch a sight that deserves watching. From high on deck, even in the smallest harbor, you can see a part of the great Norwegian fleet—fishing boats, fast commuter ferries, boats serving the offshore oil fields, sailboats on spring lines against the pier, tankers and container ships, barges with dredging shovels resting amidships, sleek powerboats, restored wooden yachts that catch the water's gleam. Here and there you might even spot a clinker-built, canoe-ended contraption that looks like a miniature tugboat, too small, too worn-out to take on the Norwegian Sea but going to sea nonetheless—a sentiment that might well be the motto all along this rugged, glorious coast. □

Nearly everyone is bilingual, speaking equally the language of earth and ocean.

Verlyn Klinkenborg often writes about special places. Orsolya and Erlend Haarberg photograph nature, mainly in the Nordic countries.





A chaos of rocky shapes called the Marble Castle was carved over centuries by the River Glomåga.

ORSOLYA HAARBERG





Erosion has shaped a landscape of sedimentary arabesques on the Varanger Peninsula.

ORSOLYA HAARBERG





Still water and the setting sun create a painterly backdrop for a stand of Scotch pines on the island of Sula—one of the many ice-scraped, sea-sculpted, barely peopled places that together create Norway's sublime shore.

ORSOLYA HAARBERG

By Pat Walters Photograph by Marco Grob

Virus Catcher

VICKI JENSEN read Richard Preston's hit book about deadly viruses, *The Hot Zone,* as a freshman in college and thought, I want to do what those guys do. Today she does. The 38-year-old is a virologist in the Biosafety Level 4 lab (aka the hot zone) at the U.S. government's Integrated Research Facility at Fort Detrick, Maryland. Her team works to develop drug treatments and vaccines for the most deadly viruses known to humanity.

How does a typical day for you begin?
You get up, and you don't drink a lot of coffee. I would have to take a seven-minute chemical decon shower just to get out for a bathroom break.

Plus you'd have to take off your airtight space suit. How does the suit work?
Your air comes in through a hose in the side. You're always tethered to something. And it's pressurized, so if it ever got punctured, air would rush out from it like a popped balloon, keeping any viruses out.

Has your suit ever popped?
No.

Seems like we don't hear much about Ebola anymore.
The number of outbreaks is on the rise. But in terms of total number of people who have died, you can't even compare it to something like flu. But it's so deadly. And there's still no proven treatment. So it's gotten a lot of attention from a biodefense perspective.

Doesn't Ebola spread only through exchanging bodily fluids?
For now. We've looked at whether someone might be able to make it aerosol transmissible—an Ebola that acts more like the flu. That's the worst-case scenario.

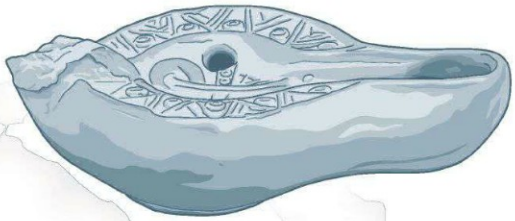
Does working with such deadly stuff frighten you?
Ya know, not really. It's funny, I do get scared about viruses sometimes. But only in uncontrolled environments. When my son was born, he was very sick. I got a stuffed doll of the Ebola virus and put it in his crib. My mom was like, "Why did you put an Ebola in his crib?" I told her, "To chase away the lesser bugs."

Does your son still have his Ebola doll?
Yeah. He's five now. He sleeps with it every night.

Watch Marco Grob's video interview with Vicki Jensen on our digital editions.




LARGE
71365-9



TURKEY

ISRAEL

BOSPORUS DIG
Istanbul, Turkey
Oil lamp, A.D. 400-500

There's no easy way to excavate for artifacts in a city of more than 13 million. But work on a new rail line to run beneath the strait that divides the city has offered glimpses of the people and empires that have come and gone here for over 8,000 years.



TEMPLE MOUNT
Jerusalem, Israel
Clay seal, 700-600 B.C.

Sacred to Judaism, Christianity, and Islam, this 36-acre site has been mostly under Muslim control since A.D. 638. Digging a new entry for a mosque in 1999 produced 6,000 tons of artifact-laden debris, an unprecedented window on the past.

Excavation Impossible

BEARING ANCIENT HEBREW LETTERS, the seal shown above came from a construction site at the Temple Mount, one of the world's holiest places. Digging is usually forbidden there, so archaeologists have taken advantage of the opportunity to sift through rubble filled with everything from arrowheads and coins to jewelry and combs. Formal archaeology can't be carried out in many places. Reasons vary: war and its aftermath, political disputes, deep-seated religious differences, cities too crowded to allow for excavation.

Sometimes—say, by dint of urban renewal—discoveries happen serendipitously. But at a growing number of sites, technologies such as ground-penetrating radar, laser scans, and virtual models are uncovering troves of information, with no digging at all. *—A. R. Williams*



PAKISTAN

CHINA

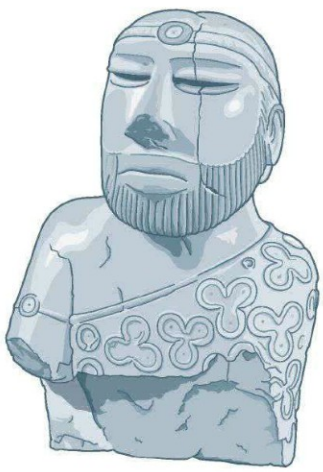
LAOS

ROYAL MAUSOLEUM
Xian, China
Bronze swan, 221-210 B.C.

China's first emperor planned a large funerary complex. His tomb and its possible treasures remain unexcavated, awaiting new techniques in artifact conservation. In 1974 his terra-cotta army was discovered, but experts have only recently learned how to preserve the paint on the figures.

MOHENJO DARO
Sindh, Pakistan
Stone figurine, 2600-1900 B.C.

Salts in the groundwater are causing exposed brick buildings to crumble at the site of this early city from the Indus civilization. It was discovered in 1922 and excavated on and off until 1965. Pakistan's government has halted further digging.



PLAIN OF JARS
Xiangkhoang, Laos
Stone urn, 500 B.C.-A.D. 500

Unexploded bombs from the 1960s and '70s, during the civil war, make it risky to examine the hundreds of jar-shaped stones, some ten feet tall, found in northern Laos. A study in the 1930s identified them as funerary urns.



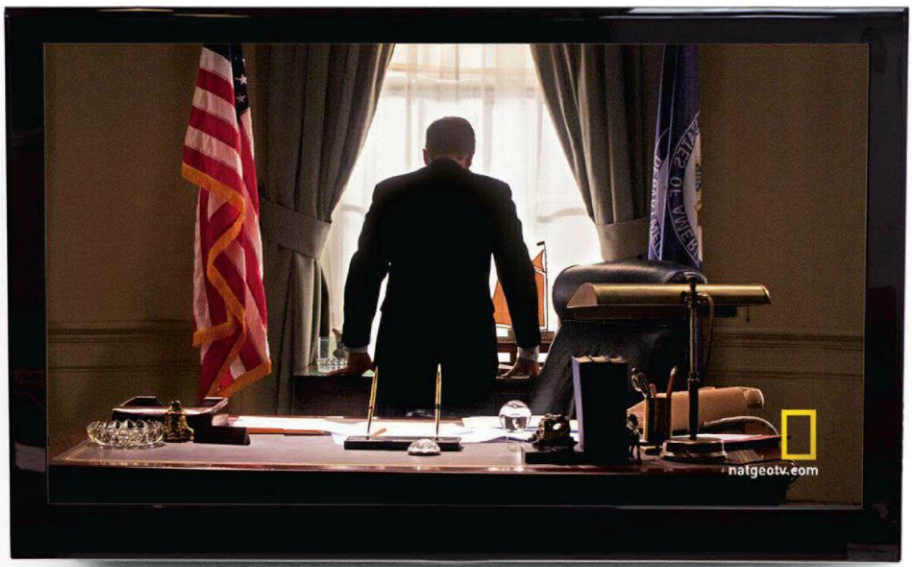
5W INFOGRAPHICS; ALEXANDER STEGMAIER AND JOHN TOMANIO, NGM STAFF

SOURCES: TEMPLE MOUNT SIFTING PROJECT; ISTANBUL ARCHAEOLOGICAL MUSEUMS; SHAANXI PROVINCIAL ARCHAEOLOGICAL INSTITUTE; NATIONAL MUSEUM OF PAKISTAN

NG CONNECT

Every month this page features our staff picks of National Geographic Society products and events. For more go to *nglive.org.*

NATIONAL GEOGRAPHIC ON TV



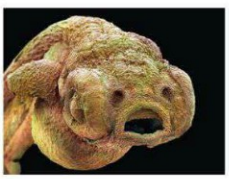
Death of a President

On November 22, 1963, America mourned as news of President John F. Kennedy's death spread. Now, 50 years later, his assassination still stands as one of the darkest points in U.S. history. Revisit the President's final years—and retrace the path that led Lee Harvey Oswald to kill him—in *Killing Kennedy,* airing this month on the National Geographic Channel.

SPEAKER

LENS OF ADVENTURE Filmmaker Bryan Smith is driven by his passion for adventure sports and conservation. Today he travels the world filming big fish for the show *Hooked.* Join him in the United States and Canada for a taste of life in the field. Visit *nglive.org* for tour dates.

FILM



MYSTERIES OF THE UNSEEN WORLD What's hiding right in front of your eyes? This 3-D film uses high-speed photography, electron microscopy, and nanotechnology to zoom in on details the human eye can't see—like the face of an embryonic zebra fish (left). In theaters November 1; details at *nationalgeographic.com/movies.*

MAP

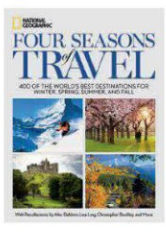
KOREAN PENINSULA North Korea's nuclear test site and Sejong, a city set to become South Korea's mini-capital, are among the latest additions to this new map of the region. Look for it at *natgeomaps.com.*

TRIP

CUBA Explore the island with historians, artists, and others who call it home. Old Havana and the city of Trinidad (right), both World Heritage sites, are on the itinerary. See *ngexpeditions.com/cuba.*



Book of the Month



Four Seasons of Travel

If you want to surf in Australia, witness animal migrations in Tanzania, or golf under the midnight sun in Iceland, timing is everything. This collection of 400 destinations reveals not only where to travel but also when. Find expert advice on festivals, sporting events, harvests, and other unforgettable experiences for every season of the year. On sale now ($40).

PHOTOS (FROM TOP): KENT EANES, NATIONAL GEOGRAPHIC CHANNEL; DAVID MCCARTHY (COLORED BY ANNIE CAVANAGH), SCHOOL OF PHARMACY, LONDON, UNITED KINGDOM; BUENA VISTA IMAGES/GETTY IMAGES

You may be entitled to claim money from a class action settlement involving American Express gift cards.

A proposed settlement in a class action lawsuit offers money to eligible users and holders of approximately 70 million American Express gift cards, plus benefits for others, including those who bought gift cards for other people. If you are included you may submit a claim form to request a payment or other benefits, or you may exclude yourself from the settlement, or object to it. The United States District Court for the Northern District of Illinois authorized this notice. Before any money is paid, the Court must decide whether to approve the settlement.

WHO'S INCLUDED?

You are included as a "Class Member" if you purchased, received, held or used a gift card issued by American Express from January 1, 2002 through September 21, 2011. If your gift card has an American Express logo on it, it is part of the settlement. A detailed notice is available which explains more about who is in the Class, as well as who is excluded.

WHAT'S THIS ABOUT?

The lawsuit claimed that American Express did not fully disclose all gift card contract terms, and misrepresented the value of the cards. The gift cards were subject to various fees, such as monthly fees and check issuance fees, resulting from trying to make transactions using a gift card and another form of payment. American Express denies that it did anything wrong, and the Court did not decide which side was right.

SETTLEMENT BENEFITS.

The settlement offers from $5 to $20 per gift card ($40 per Class Member) from a fund of about $2.7 million. Depending on how many valid claims are received, each payment could be less, but not more. Unclaimed money will go to charity. If you bought a card and gave it to someone else, *e.g.*, as a gift, you cannot get a payment for that card. However, the settlement allows all Class Members to buy a new $100 gift card without purchase/shipping/handling fees, and lets anyone who has an American Express gift card, or a gift card number without the actual card, with a value of $25 or less to get a refund of the unused balance at no cost.

HOW TO GET A PAYMENT.

You must submit a claim form by March 6, 2014, to ask for a payment or other benefits. Go to the website below, or call 1-866-680-3343 to get a claim form. You may file a claim even if you do not have your gift card or gift card number. If so, American Express will compare your claim form to its gift card transaction data in order to verify your claim and determine your payment.

YOUR OTHER RIGHTS.

If you don't want to be legally bound by the settlement, you must exclude yourself by **March 6, 2014**, or you won't be able to sue, or continue to sue, American Express about the legal claims in this case. If you exclude yourself, you can't get any money from this settlement. If you stay in the settlement, you may object to it by **March 6, 2014**. If the settlement is approved, it releases American Express from liability as fully explained in the Settlement Agreement available at the website below.

The Court will hold a fairness hearing on the settlement in *Kaufman v. American Express*, No. 07-01707 on **June 11, 2014**, to consider whether to approve the settlement and a request by the lawyers representing Class Members (Bock & Hatch LLC and also Morris and Associates) for $1,529,000 in fees and costs, and also $1,000 incentive awards for each Class representative (Saul Kaufman, Kimberly Stegich, Gordon Jarratt, and Amanda Rudd). You or your own lawyer may ask to appear and speak at the hearing, at your own cost, but you don't have to. The detailed notice explains how to exclude yourself, object, or appear in Court. To learn more, call **866-680-3343**, visit the website below, or write to Kaufman Settlement Administrator, P.O. Box 8015, Faribault, MN 55021-9415.

866-680-3343 www.KaufmanClassActionSettlement.com

Reef Madness

The Pacific reef at Kimbe Bay seemed like paradise to photographer David Doubilet when he visited 17 years ago. But his recent return was more like a stop in photographic purgatory. Shooting was delayed by heavy rains and floods. Visibility was at times limited to ten feet. Several cameras became waterlogged. His wife and collaborator, Jennifer Hayes, came down with malaria. The clouds relented in spurts, allowing him to capture corals and marine life, like the school of pinjalo snappers below. The day before he left, the rain finally stopped. *—Daniel Stone*



BEHIND THE LENS

What attracted you to these pinjalo snappers?

DD: The fish were remarkable. They would quickly change color from silver to blood orange to red as they swam by. They reminded me of a painting. I was intoxicated by their color, the way they swam, and their complete lack of fear. The school would pass by me within inches or sometimes remain very close to me. We dove this area again and again. I was addicted to these fish.

At one point you questioned whether to scrap the story.

I did. On a scouting dive there were dense gardens of the largest sea fans I had ever seen exploding with fish, color, and beauty. Except it was all veiled from my camera by extremely low visibility because of the rain. Everything I had come for was right in front of my eyes but nearly invisible. I was mad, panicked, and depressed. A failed assignment would have been deeply personal for me. We needed a plan B.

What did you do?

We made day trips to reach deep offshore reefs within commuting distance from shore. The downsides were deeper dives and less time to shoot. The upside was the beauty we finally got to see.

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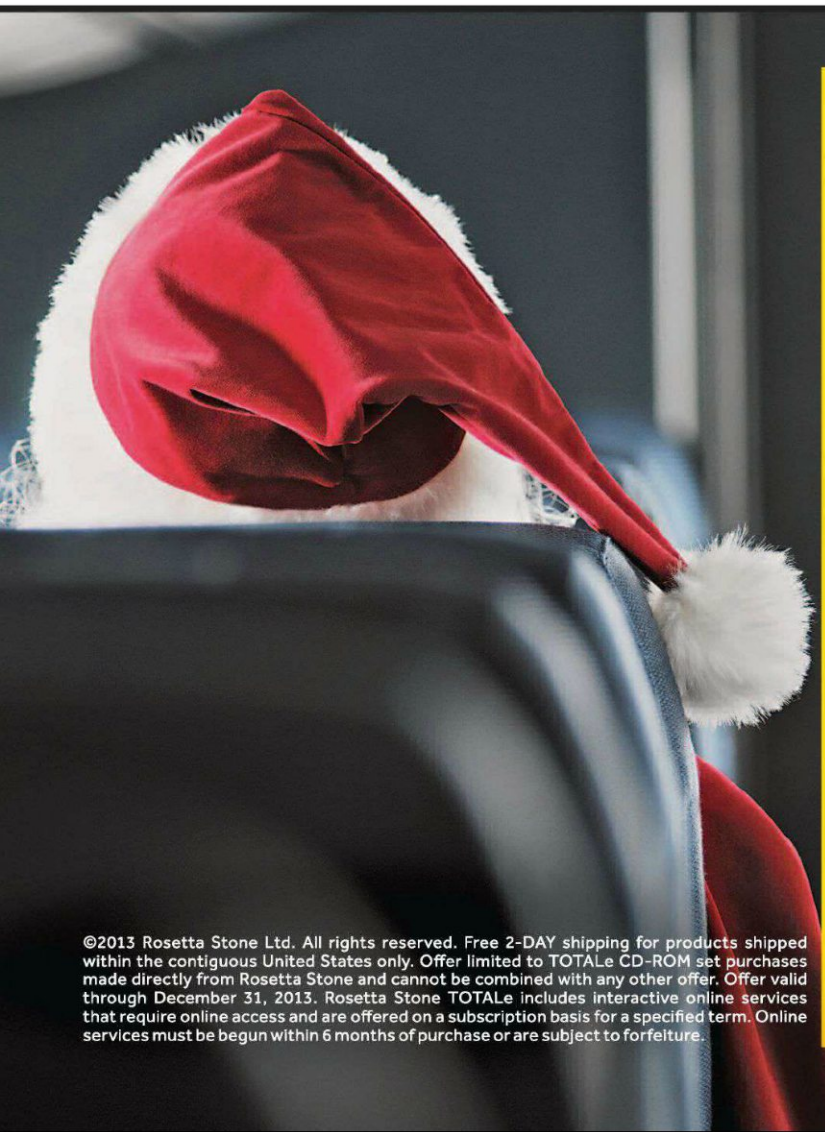
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Once Upon a Smokestack Haze jostles clouds in the sky over Hunedoara, Romania, in this photo from the November 1975 *National Geographic.* The town's metalworks, which opened in 1884, was once the most prolific steel producer in the country. "Two of Hunedoara's new open-hearth furnaces alone produce twenty times as much steel as did the entire plant a generation ago," notes the caption to this photo in the magazine. The end of Communism in Romania in 1989 slowed the local industry. Now under private ownership, much of the old steelworks has been demolished.

Another old structure in Hunedoara still stands though. Constructed largely during the 15th century, Corvin Castle (at center right) was home to generations of nobles. Among the Transylvanian castle's visitors was Vlad III, who is perhaps better known as Vlad the Impaler—author Bram Stoker's inspiration for Count Dracula. *—Margaret G. Zackowitz*

Get Lost in Found. Go to **NatGeoFound.tumblr.com.**

PHOTO: WINFIELD PARKS, NATIONAL GEOGRAPHIC CREATIVE

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Sociable Lapwing *(Vanellus gregarius)*
Size: Head and body length, 27 - 30 cm (10.6 - 11.8 inches); wingspan, 70 - 76 cm (27.6 - 29.9 inches) **Weight:** 150 - 260 g (5.3 - 9.2 oz) **Habitat:** Breeds in steppes; in non-breeding season prefers sandy short grass plains and meadows **Surviving number:** Estimated at 11,000

Photographed by Hanne & Jens Eriksen

WILDLIFE AS CANON SEES IT

Frequent flyer. The sociable lapwing's mysterious migratory routes take it from its breeding grounds in the steppes of Kazakhstan and Russia to locations throughout the Middle East. It has even been found as far south as Sudan and as far east as India. The well-traveled bird is monogamous, making a simple scrape its nest and laying a single clutch per season, almost always of four eggs. If the first clutch fails, it may be replaced. But it is not as easy to rebound from the 70% decline in population that occurred with the loss of habitat in the 20th century. Illegal hunting is the main threat to the wide-ranging flyer today.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit **canon.com/environment** to learn more.

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